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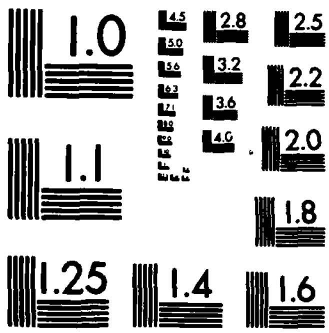

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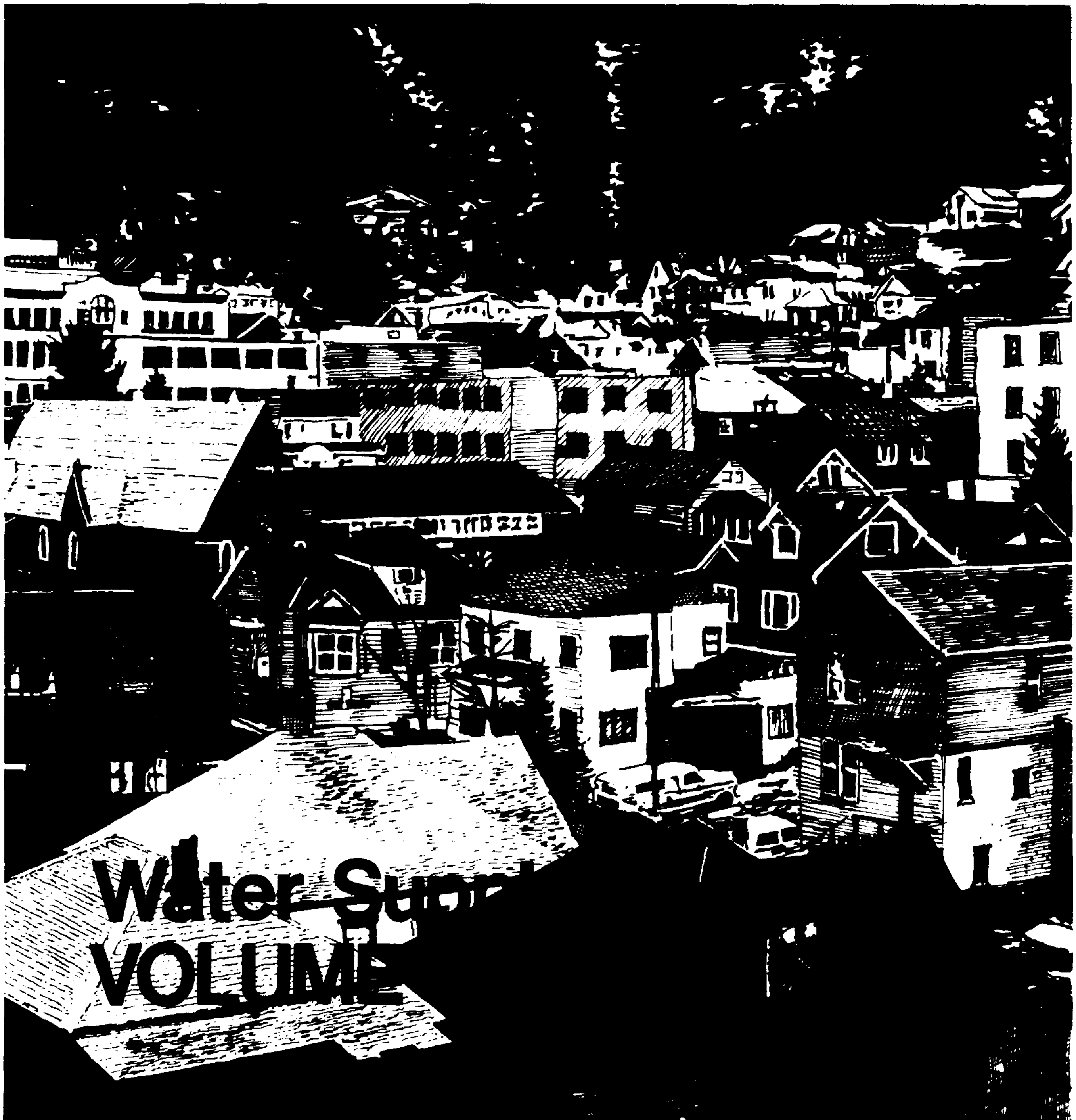

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FARGO-MOORHEAD URBAN STUDY

WATER SUPPLY APPENDIX

VOLUME II

PHASE 2
ALTERNATIVE SOURCES
AND
TREATMENT/DISTRIBUTION SYSTEMS

St. Paul District, Corps of Engineers
1135 U.S. Post Office and Custom House
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FARGO (NORTH DAKOTA)
MOORHEAD (MINNESOTA)
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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

The Fargo-Moorhead Urban Study is a cooperative Federal, State and local planning effort aimed at developing viable solutions to water and related land resource problems, needs and concerns for 1980-2030.

The summary report contains a brief, non-technical overview. Readers desiring additonal detailed information should review the appropriate technical appendixes.

The objective of this study was to develop water demand projections for

the Fargo-Moorhead area for the planning period 1980-2030. Phase 2 involves the evaluation of alternative water sources and water treatment and distribution systems.

PREFACE

The Fargo-Moorhead Urban Study was sponsored by the St. Paul District, Corps of Engineers, as a cooperative effort of local, State, and Federal agencies. The results of this study are contained within the following documents:

- Summary Report
- Background Information Appendix
- Water Supply Appendix (3 Volumes)
- Water Conservation Appendix
- Energy Conservation Appendix
- Flood Control Appendix
- Fargo-Moorhead Water Resource Data Management System Appendix (3 Volumes)

The Summary Report contains a brief, non-technical overview of the results of the overall study. Only readers desiring additional detailed information should review the appropriate technical appendixes.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF FIGURES

APPENDIX A

DISAGGREGATED WATER DEMANDS

(Revised October 1983)

APPENDIX A

DISAGGREGATED WATER DEMANDS WITHIN RESIDENTIAL, COMMERCIAL, AND INDUSTRIAL SECTORS

Tables A-1 through A-9 in this appendix supplement the tables in Chapters III and V of the main text for Fargo, Moorhead, and West Fargo. These appendix tables offer additional information about the water use within each sector, including information that was used to develop projected demands. It is important to note that the sum of maximum daily and peak hour water use values for each sector is only an index value. This sector sum assumes all components have peak uses coincident in time, where in actuality every component could peak independently. In order to overcome the implications of this approach, maximum daily municipal use is calculated using historic relations between aggregate average annual daily use and aggregate maximum daily use.

The first table for each community presents base year and projected residential demands. Base year annual average use is based on historical utility records of per residential connection use. This rate of consumption is assumed to remain constant throughout the projection period. However, the population per connection is forecast to decrease slightly, simulating a small increase in per capita consumption with time. Maximum-day and peak-hour values were calculated from annual average demand using coefficients derived from MAIN II System computer runs.

Residential water use represents the product of the number of units and use-per-unit coefficient. The total number of housing units is projected from population projections and projected occupancy per housing unit. The division of the total units among single-family, multiple-family, and mobile home categories is based on existing housing data.

Base-year commercial demands for each community are calculating using actual data collected from the communities. Demands are calculated from coefficients from Hittman and Associates (1969) or actual utility records. The commercial demands are presented in two portions to facilitate projections of future demands.

Commercial demands are mainly projected according to OBERS total services employment projections. Those types with closely related parameters for which better data exist were projected independently. Portion 1 contains all types of commercial establishments whose demands were assumed to increase similarly according to total services employment. Portion 2 contains the types that were projected independently. Retail demand is estimated from OBERS-projected retail employment, and school and college needs are estimated from enrollment projections. Multiple-family and mobile home demands have been previously discussed in the residential section of this appendix.

Base year industrial demands were estimated from utility records and employment estimates from various sources. The majority of the industrial water use is estimated from utility records. Projected industrial demand is based on OBERS-projected industrial employment values.

FARGO

TABLE A-1

RESIDENTIAL WATER DEMAND - FARGO

(million gallons per day)

	YEAR 1980			YEAR 1990			YEAR 2000			YEAR 2030		
	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour
Single Family Residential	2.96	12.73	29.01	3.38	14.53	33.12	3.64	15.65	35.67	4.72	20.30	46.26

NOTE: Residential average annual water demand based directly on the number of single family water service connections.

Maximum day and peak hour demands based on MAIN II System computer runs.

Average annual demand for 1980 actually based on 1977-1981 averages.

TABLE A-2

PROJECTED COMMERCIAL WATER DEMAND - FARGO

(gallons per day)

Type of Commercial Establishment	YEAR 1990 Average Annual	YEAR 1990 Maximum Day	YEAR 1990 Peak Hour	YEAR 2000 Average Annual	YEAR 2000 Maximum Day	YEAR 2000 Peak Hour	YEAR 2030 Average Annual	YEAR 2030 Maximum Day	YEAR 2030 Peak Hour
TOTAL-Portion 1	1,664,264	3,300,576	8,447,256	1,780,813	3,531,716	9,038,819	2,060,128	4,085,655	10,456,530
Portion 2:									
Multiple Fam.Homes	1,284,465	1,926,698	10,569,312	1,423,170	2,134,755	11,710,656	2,254,665	3,381,998	18,552,672
Mobile Homes	287,271	430,906	1,869,696	309,927	464,890	2,017,152	403,383	605,074	3,625,408
Retail Space	144,980	210,256	369,996	156,994	228,699	402,452	168,826	245,298	431,662
Schools:									
Elementary	34,200	61,500	312,000	36,600	65,800	334,000	51,000	91,700	465,000
High	15,700	46,500	287,000	16,800	49,800	307,000	23,500	69,400	428,000
Colleges	422,532	455,202	997,524	422,532	455,202	997,524	422,532	455,202	997,524
TOTAL (Portion 1 and Portion 2)	4,019,627	6,680,960	24,220,496	4,375,736	7,274,212	26,691,123	5,613,039	9,277,934	35,841,180
TOTAL in million gallons per day	4.02	6.68	24.22	4.38	7.27	26.69	5.61	9.28	35.84

NOTE: Demands for Portion 1 of the commercial sector were projected from base year (1980) values using a ratio of Fargo's projected total services employment and base year total services employment. Total values Portion 1 reflect the combined demands of all Portion 1 commercial establishment types. Demand values for individual types can be calculated in the same manner (from base year data using projected Fargo total services employment figures).

Portion 2 demands of each commercial type are projected independently.

TABLE A-3

PROJECTED INDUSTRIAL WATER DEMAND - FARGO

(gallons per day)

		YEAR 1990			YEAR 2000			YEAR 2030		
S.I.C. Code	Industry Description	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour
202	Dairies	47,639	47,639	52,403	57,903	57,903	63,694	73,257	73,257	80,583
203	Specialty Foods	47,639	47,639	52,403	57,903	57,903	63,694	73,257	73,257	80,583
204	Grain Mills	43,134	43,134	47,448	52,427	52,427	57,670	66,329	66,329	72,962
205	Bakery Products	50,186	50,186	55,204	60,999	60,999	67,098	77,174	77,174	84,890
208	Beverages	142,915	142,915	157,206	173,707	173,707	191,078	219,767	219,767	241,744
230	Whl. Apparel Ind.	348	348	383	423	423	465	535	535	588
243	Millwork	4,579	4,579	5,037	5,565	5,565	6,122	7,041	7,041	7,745
251	Home Furniture	8,852	8,852	9,737	10,759	10,759	11,835	13,612	13,612	14,974
264	Paper Products	7,577	7,577	8,335	9,209	9,209	10,130	11,651	11,651	12,817
265	Paperboard Boxes	2,692	2,692	2,962	3,272	3,272	3,600	4,140	4,140	4,554
270	Whl. Print Ind.	26,365	26,365	29,000	32,045	32,045	35,249	40,542	40,542	44,595
282	*Plastic	53,307	53,307	58,638	64,793	64,793	71,272	81,973	81,973	90,171
306	**Rubber Products	18,113	18,113	19,924	22,015	22,015	24,217	27,853	27,853	30,638
307	Plastic Products	26,012	26,012	28,613	31,617	31,617	34,778	40,001	40,001	44,000
327	Cement	56,937	56,937	62,630	69,205	69,205	76,124	87,555	87,555	96,309
328	Cut Stone	2,324	2,324	2,556	2,825	2,825	3,107	3,574	3,574	3,931
343	Plumbing	14,909	14,909	16,400	18,121	18,121	19,933	22,926	22,926	25,219
344	Structure Metal	23,332	23,332	25,665	28,359	28,359	31,194	35,878	35,878	39,466
347	**Metal Services	47,639	18,113	52,403	22,015	22,015	24,217	27,853	27,853	30,638
	SUBTOTAL:	624,499	594,973	686,947	723,162	723,162	795,477	914,918	914,918	1,006,407

TABLE A-3 (continued)

PROJECTED INDUSTRIAL WATER DEMAND - FARGO

(gallons per day)

S.I.C. Code	Industry Description	YEAR 1990 Average Annual	YEAR 1990 Maximum Day	YEAR 1990 Peak Hour	YEAR 2000 Average Annual	YEAR 2000 Maximum Day	YEAR 2000 Peak Hour	YEAR 2030 Average Annual	YEAR 2030 Maximum Day	YEAR 2030 Peak Hour
	SUBTOTAL:	630,930	630,930	726,499	766,866	766,866	843,551	970,211	970,211	1,067,228
353	Construction Equipment	1,265	1,265	1,391	1,538	1,538	1,691	1,945	1,945	2,139
355	Special Industrial Equipment	1,684	1,684	1,852	2,047	2,047	2,251	2,589	2,589	2,848
359	Misc. Machine Work	23,895	23,895	26,285	29,044	29,044	31,948	36,745	36,745	40,420
362	Electric Industrial Apparatus	12,658	12,658	13,925	15,386	15,386	16,925	19,466	19,466	21,413
369	Electric Products	19,362	19,362	21,297	23,533	23,533	25,886	29,773	29,773	32,750
371	Motor Vehicles	13,363	13,363	14,699	16,242	16,242	17,866	20,548	20,548	22,603
384	Medical Instrument	6,599	6,599	7,258	8,021	8,021	8,822	10,147	10,147	11,161
399	Misc. Manufacturing	9,346	9,346	10,281	11,360	11,360	12,496	14,372	14,372	15,809
	INDUSTRIAL TOTAL:	719,102	719,102	823,487	874,037	874,037	961,436	1,105,796	1,105,796	1,216,371
TOTAL in million gallons per day		0.72	0.72	0.82	0.87	0.87	0.96	1.11	1.11	1.22

NOTE: Average annual demand projections based on associated base year (1980) demand and OBERS projected manufacturing employment.

Industrial peak hour demand assumed to be 10 percent greater than average annual use.

MOORHEAD

TABLE A-4

RESIDENTIAL WATER DEMAND - MOORHEAD

(million gallons per day)

	YEAR 1980			YEAR 1990			YEAR 2000			YEAR 2030		
	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour
Single Family Residential	1.66	6.97	16.27	1.76	7.39	17.25	1.93	8.11	18.91	2.16	9.07	21.17

NOTE: Residential average annual water demand based directly on the number of single family water service connections.

Maximum day and peak hour demands based on MAIN II System computer runs.

TABLE A-5

PROJECTED COMMERCIAL WATER DEMAND - MOORHEAD
(gallons per day)

Type of Commercial Establishment	YEAR 1990			YEAR 2000			YEAR 2030		
	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour
TOTAL-Portion 1	489,500	1,065,000	2,596,000	554,000	1,206,000	2,938,000	637,500	1,388,000	3,381,000
Portion 2:									
Multiple-Family Homes	484,680	727,020	3,988,224	604,485	906,728	4,974,048	772,170	1,158,255	6,353,856
Mobile Homes	84,783	127,174	551,808	109,032	163,548	709,632	143,016	214,524	930,816
Retail	55,871	81,081	142,682	60,579	88,011	154,877	64,946	94,248	165,852
Schools:									
Elementary	14,400	26,000	132,000	16,600	29,800	151,000	19,600	35,300	179,000
High	7,210	21,300	132,000	8,290	24,500	151,000	9,800	29,000	179,000
Colleges	272,512	293,802	642,958	272,512	293,802	642,958	272,512	293,802	642,958
TOTAL (Portion 1 and Portion 2)	1,408,956	2,341,377	8,185,672	1,625,498	2,712,389	9,721,515	1,919,544	3,213,129	11,832,482
TOTAL in million gallons per day	1.41	2.34	8.19	1.63	2.71	9.72	1.92	3.21	11.83

NOTE: Demands for Portion 1 of the commercial sector were projected from base year (1980) values using a ratio of Moorhead's projected total services employment and base year total services employment. Total values Portion 1 reflect the combined demands of all Portion 1 commercial establishment types. Demand values for individual types can be calculated in the same manner (from base year data using projected Moorhead total services employment figures).

Portion 2 demands of each commercial type are projected independently.

TABLE A-6

PROJECTED INDUSTRIAL WATER DEMAND - MOORHEAD

(gallons per day)

S.I.C. Code	Industry Description	YEAR 1990 Average Annual	YEAR 1990 Maximum Day	YEAR 1990 Peak Hour	YEAR 2000 Average Annual	YEAR 2000 Maximum Day	YEAR 2000 Peak Hour	YEAR 2030 Average Annual	YEAR 2030 Maximum Day	YEAR 2030 Peak Hour
206	Sugar Production and Research	474,340	474,340	521,774	507,397	507,397	558,137	545,711	545,711	600,282
208	Beverages	58,435	58,435	64,278	62,507	62,507	68,757	67,227	67,227	73,949
208	Malting Plant	1,004,503	1,004,503	1,104,953	1,074,508	1,074,508	1,181,959	1,155,645	1,155,645	1,271,210
251	Home Furniture	2,299	2,299	2,529	2,459	2,459	2,705	2,645	2,645	2,910
270	Wholesale Print Industry	504	504	554	539	539	593	580	580	637
327	Cement	7,852	7,852	8,637	8,399	8,399	9,239	9,033	9,033	9,937
344	Structural Metal	14,193	14,193	15,612	15,182	15,182	16,700	16,328	16,328	17,961
359	Misc. Machining	964	964	1,061	1,031	1,031	1,135	1,109	1,109	1,220
369	Electrical Products	7,931	7,931	8,724	8,484	8,484	9,332	9,125	9,125	10,037
371	Motor Vehicles	6,417	6,417	7,059	6,865	6,865	7,551	7,383	7,383	8,121
373	Boat Building	2,680	2,680	2,947	2,866	2,866	3,153	3,083	3,083	3,391
398	Administrative/ Auxiliary Staff	4,907	4,907	5,398	5,249	5,249	5,774	5,646	5,646	6,210
	Misc. Manufacturing	2,431	2,431	2,674	2,600	2,600	2,861	2,797	2,797	3,077
INDUSTRIAL TOTAL		1,587,456	1,587,456	1,746,200	1,698,086	1,698,086	1,867,896	1,826,312	1,826,312	2,008,942
TOTAL in million gallons per day:		1.59	1.59	1.75	1.70	1.70	1.87	1.83	1.83	2.01

NOTE: Average annual demand projections based on associated base year (1980) demand and OBERS projected manufacturing employment.

Industrial peak hour demand assumed to be 10 percent greater than average annual use.

WEST FARGO

TABLE A-7

RESIDENTIAL WATER DEMAND - WEST FARGO

(million gallons per day)

	YEAR 1980			YEAR 1990			YEAR 2000			YEAR 2030		
	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour
Single-Family Residential	0.50	1.80	2.87	0.60	2.20	3.50	0.73	2.66	4.25	1.50	3.82	6.09

NOTE: Residential average annual water demand based directly on the number of single family water service connections.

Maximum day demand based on relations between the number of single family housing units and their density per residential acre as developed by Clark et al (1971) and Lakshman (1976).

TABLE A-8

PROJECTED COMMERCIAL WATER DEMAND - WEST FARGO
(gallons per day)

Type of Commercial Establishment	YEAR 1990 Average Annual	YEAR 1990 Maximum Day	YEAR 1990 Peak Hour	YEAR 2000 Average Annual	YEAR 2000 Maximum Day	YEAR 2000 Peak Hour	YEAR 2030 Average Annual	YEAR 2030 Maximum Day	YEAR 2030 Peak Hour
TOTAL-Portion 1	55,476	140,600	351,490	61,024	154,660	386,639	81,197	205,787	514,453
Portion 2:									
Multiple-Family Homes	212,835	319,252	1,751,328	319,200	478,800	2,626,560	583,590	875,385	4,802,112
Mobile Homes	96,111	144,166	625,536	116,997	175,496	761,472	169,035	253,552	1,100,160
Schools:									
Elementary	16,603	29,872	151,523	19,793	35,613	180,639	30,010	53,995	273,880
High	6,875	20,325	125,477	8,201	24,245	149,677	12,431	36,750	226,875
Subtotal Portion 2	332,424	513,615	2,653,864	464,191	714,154	3,718,348	795,066	1,219,682	6,403,027
TOTAL (Portion 1 and Portion 2)	387,900	654,215	3,005,354	525,215	868,814	4,104,987	876,263	1,425,469	6,917,480
TOTAL in million gallons per day	0.39	0.65	3.01	0.53	0.87	4.10	0.88	1.43	6.92

NOTE: *Portion 1 commercial sector demand assumed to grow 10 percent per decade.*

Portion 2 demands projected independently.

TABLE A-9

PROJECTED INDUSTRIAL WATER DEMAND - WEST FARGO
(gallons per day)

		YEAR 1990			YEAR 2000			YEAR 2030		
S.I.C. Code	Industry Description	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour
201	Meat Products	7,233	7,233	7,955	7,956	7,956	8,751	10,586	10,586	11,644
327	Cement	779	779	857	857	857	943	1,140	1,140	1,254
344	Structural Metal	196	196	216	215	215	237	287	287	316
349	Fabricated Metal	2,683	2,683	2,951	2,951	2,951	3,246	3,927	3,927	4,320
359	Misc. Machining	7,887	7,887	8,676	8,676	8,676	9,543	11,544	11,544	12,698
371	Motor Vehicles	7,955	7,955	8,751	8,751	8,751	9,626	11,644	11,644	12,808
	INDUSTRIAL TOTAL:	26,733	26,733	29,406	29,406	29,406	32,346	39,128	39,128	43,040
TOTAL in million gallons per day:		0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04

NOTE: Peak hour estimated to be 10% greater than annual average use.

Employment data from Fargo-Moorhead Directory of Manufacturers and Fargo Job Service.

I. SUMMARY

In response to local concerns about future water supplies, the U.S. Army Corps of Engineers sponsored a water supply/conservation investigation as part of the Fargo-Moorhead Urban Study. This report describes the work done in Phase 2 of the three-phase investigation by Eugene A. Hickok and Associates under contract to the Corps of Engineers. Locally, guidance has come through the Fargo-Moorhead Metropolitan Council of Governments' Water Resources Committee. In addition, the investigation included several surveys of all 18 study area communities to obtain critical information regarding water use and municipal water supply facilities. The results of the investigation should provide valuable information to area planners regarding municipal water use and potential resource development.

In this study, a fundamental distinction has been made between the urban core communities of Fargo, Moorhead, West Fargo, and Dilworth and the remaining study area communities. The smaller communities in the latter group all rely on ground water and can meet projected future water needs with localized expansions of their water supply facilities. The water resources required for the smaller communities were allowed for in the analysis of water supply alternatives for the urban core.

Using existing facilities and resources as a basis, the urban core communities are projected to require an additional 30.24 million gallons of water per day under extreme conditions in the year 2030. These conditions include 7-day, 50-year drought flows in both the Red and Sheyenne Rivers, coincident with projected maximum day water demands plus fire-flow requirements.

Of the five study area rivers investigated, the Red and Sheyenne Rivers are identified as logical future sources of part of the water supply for the urban core communities. Ground-water aquifers in the study area are also available for further development. In addition, the Sheyenne Delta Aquifer represents a very large potential water supply source outside the study area.

The proposed Garrison Diversion would increase streamflows in the Red and Sheyenne Rivers. If fully implemented, the diversion would slightly decrease the cost of future water supply facilities required for the urban core communities. However, the cost ranking of long-term alternative water supply schemes would not be affected.

Water supply alternatives in this study were based on two methods of determining in-stream flow requirements for the Red and Sheyenne Rivers: the Tennant criteria (primarily requiring river withdrawals to cease when streamflows would fall below 30 percent of the annual means) and the Souris-Red-Rainy River Basins Comprehensive Study (SRR) criteria (requiring maintenance of at least 7 and 3 cubic feet per second, respectively, in the Red and Sheyenne Rivers). Under normal flows, the two methods are equivalent. During any but the most severe droughts, Tennant-based alternatives would result in greater streamflows than SRR-based alternatives. However, costs for Tennant-based alternatives are considerably greater. In more detailed stages of planning, studies should be conducted to determine the streamflow needs in the study area more accurately.

Interconnections of Fargo with West Fargo and Moorhead with Dilworth appear to be necessary for supplying water to the urban core communities in the most cost-effective manner in the future. An interconnection from Fargo to West Fargo could have legal bearing on the retention of West Fargo's water rights to the Sheyenne River and Lake Ashtabula.

An interconnection between the two largest communities, Fargo and Moorhead, also appears to be desirable for several reasons:

- Moorhead-Dilworth cannot meet year 2000 demands under drought conditions without additional storage. The interconnection would delay the need for reservoir construction.

- The interconnection would allow new ground-water treatment process expansion to take place primarily at the Moorhead plant and new surface-water treatment expansion to take place primarily at the Fargo plant. Not only would this provide economies of scale and continuity at the treatment plants, it would also simplify raw water piping schemes.

- The interconection would benefit both parties. No cross-flow need occur under normal conditions. In times of drought, cross-flow could occur in either direction.

The least costly sources of supply vary somewhat based on the quantities required from the sources; however, a generalized rank order, subject to specific exceptions, is as follows:

1. Expand Kragnes Aquifer
2. Expand Moorhead Aquifer
3. Expand Buffalo Aquifer
4. Construct in-stream storage
5. Construct off-stream storage
6. Develop West Fargo South Aquifer
7. Develop Sheyenne Delta Aquifer

Other factors being equal (costs, environmental impacts, social impacts, etc.), ground-water sources are preferred over surface-water storage. Although both sources have been sized to satisfy 50-year drought demands, ground-water supplies continue to provide water under more extreme droughts. When the surface-water storage volume is consumed, no more is available.

Of the alternative water supply schemes considered in this study, one exhibits an optimal development of future water supply facilities. This alternative, designated Alternative VI (SRR), utilizes interconnections between the urban core communities and develops the least costly sources of new water supply. It is based on the SRR criteria for in-stream flow needs. Under this approach, the four urban core communities would be interconnected to form a subregional water supply system. The plan augments existing facilities with expanded development of the Kragnes, Moorhead, and Buffalo Aquifers, and construction of a larger Red River low-head dam. Alternative VI (SRR) is one of the two least-cost alternatives and has a significantly lower adverse impact than the other. Total present value capital costs and operation, maintenance, and repair costs are $5,891,000 and $3,154,000, respectively. These are equivalent to approximately $860,000 per year over the 46-year planning period based on a Federal discount rate of 9.352 percent.

Phase 3 of the Fargo-Moorhead Urban Study will address the practicality of water conservation and its effects on this water supply plan.

It is recommended that study area communities lay the legal, fiscal, and administrative groundwork for a subregional water supply facility. Initial work would include preparation for constructing interconnections between Fargo and West Fargo and between Moorhead and Dilworth. Subsequent work would involve planning for the additional facilities required to serve Fargo and Moorhead jointly, as well as West Fargo and Dilworth.

It is also recommended that several studies be conducted in connection with in-stream reservoir storage on the Red River. These studies are prerequisites to enlarging the existing reservoir for the benefit of the urban core communities.

Local, State, and Federal interests must cooperate in developing and implementing an equitable and mutually acceptable water supply plan for the Fargo-Moorhead urban study area.

II. INTRODUCTION

As part of the Fargo-Moorhead Urban study, the St. Paul District, U.S. Army Corps of Engineers, sponsored a series of water supply/conservation investigations. Phase 1 of these investigations made preliminary demand projections and analyzed low-flow characteristics of area streams. Phase 2 investigated alternative approaches to future water supply for the Fargo-Moorhead area, and is the subject of this report. Phase 3 focused on water conservation.

The Phase 2 study developed a broad base of information on existing water supply facilities and on potential and currently used surface and ground-water resources of the area. Water demand projections through the year 2030 were refined using detailed demographic and economic projections. Future water supply and treatment needs were identified by projecting the consequences of a no-action alternative. Finally, alternative schemes for meeting the projected needs were developed and analyzed. The analysis includes preliminary cost estimates and assessment of social and environmental impacts.

Figure 1 depicts the study area. It includes Harwood, Fargo, Raymond, Mapleton, Reed, Barnes, and Stanley Townships of Cass County, North Dakota, and Kragnes, Oakport, Moorhead, Glyndon, Kurtz, and Elmwood Townships of Clay County, Minnesota. Major population centers are the cities of Fargo, Moorhead, West Fargo, and Dilworth, the study area's "urban core."

The study area is within the Red River of the North basin and includes portions of the Red River, Sheyenne River, Buffalo River, South Branch Buffalo River, Maple River, and Wild Rice River. There are a number of ground-water aquifers in and near the study area. In addition, the proposed Garrison Diversion Unit to the west of the study area may in the future supply water to the basin.

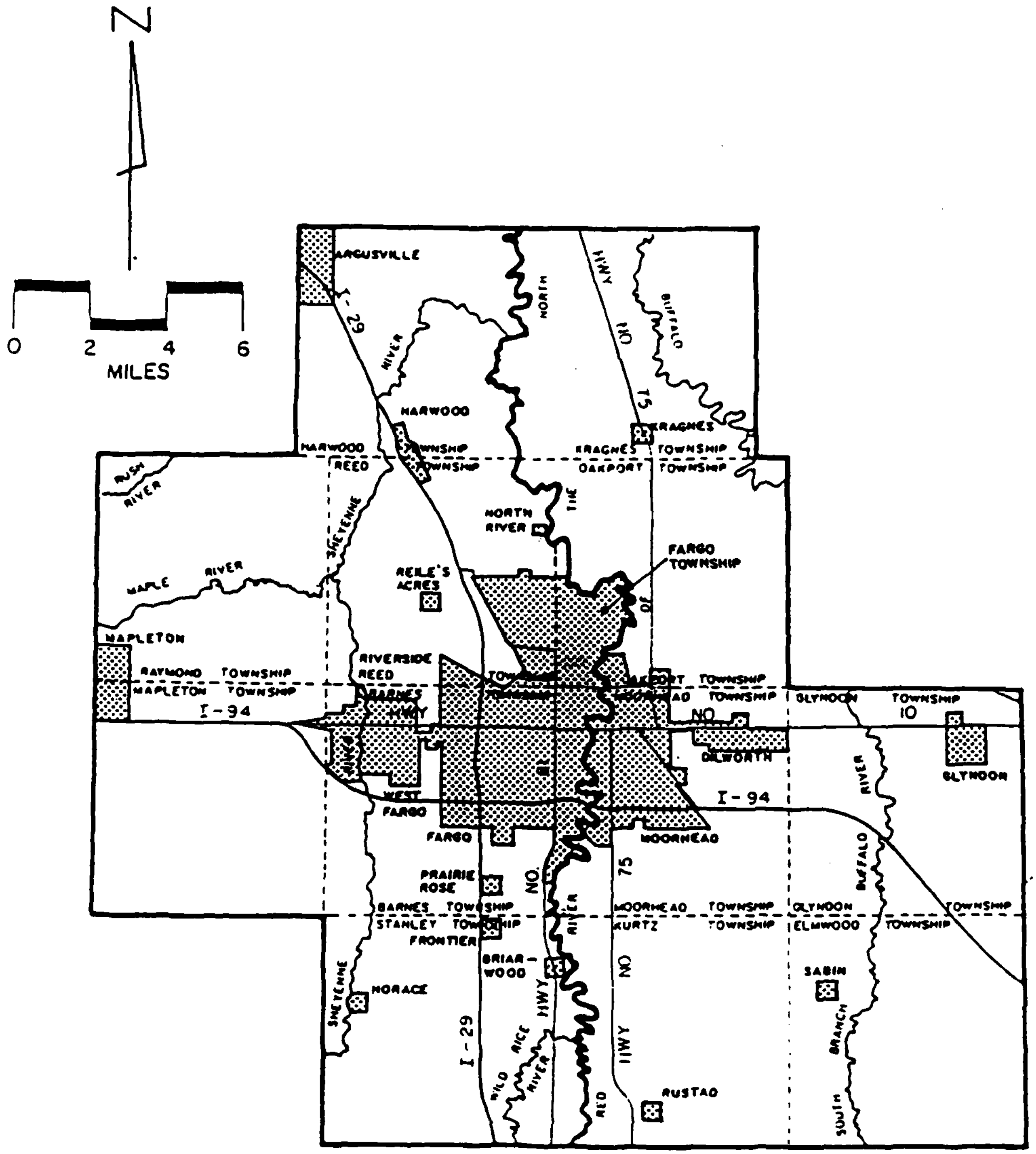


FIGURE 1
Fargo-Moorhead Study Area

III. EXISTING FACILITIES AND WATER USE

A. GENERAL

Existing municipal water facilities include the treatment and distribution facilities and the wastewater treatment system. The treatment and distribution facilities are designed to meet maximum daily municipal demands at State drinking water standards. These facilities include source-to-plant, treatment plant, water storage, and distribution facilities. The wastewater treatment systems are designed to treat maximum return flow and meet specific discharge standards. Because there are several major types of wastewater treatment processes, these facilities may include different series of components. In this section, existing water facilities will be described on a community-by-community basis after a brief discussion of water quality standards.

More detailed information exists for the large communities in the urban area. For this reason, these communities are discussed first. Information about each smaller community is presented in a simplified format, and existing water supply facilities for all small communities are summarized for reference in Table 19 following subsection C.

B. EXISTING STANDARDS FOR DRINKING WATER AND OTHER SPECIFIC USES

The Minnesota and North Dakota Departments of Health both have primary drinking water standards for public water supplies (Table 1). Included are maximum contaminant levels for various inorganic constituents, pesticides and other organic compounds, radionuclides, total coliform bacteria, and turbidity.

Because the standards for the two States closely follow Federal guidelines under the Safe Drinking Water Act, they are practically identical. Minnesota has adopted a slightly more stringent fluoride standard than has North Dakota (2.2 versus 2.4 milligrams per liter).

TABLE 1

DEPARTMENT OF HEALTH PRIMARY DRINKING WATER STANDARDS*

	Maximum Contaminant Levels (MCL) (milligrams per liter) Minnesota	North Dakota
Inorganics		
Arsenic	0.05	0.05
Barium	1.	1.
Cadmium	0.010	0.010
Chromium	0.05	0.05
Fluoride	2.2	2.4
Lead	0.05	0.05
Mercury	0.002	0.002
Nitrate (as N)	10.	10.
Selenium	0.01	0.01
Silver	0.05	0.05
Organics		
Chlorinated Hydrocarbons:		
Endrin	0.0002	0.0002
Lindane	0.004	0.004
Methoxychlor	0.1	0.1
Toxaphene	0.005	0.005
Chlorophenoxys:		
2,4-D	0.1	0.1
2,4,5-T P Silvex	0.01	0.01
Total THMs**	0.10	0.10
Radionuclides		
Combined radium 226 and radium 228	5 picocuries per liter	5 picocuries per liter
Gross alpha particle activity***	15 picocuries per liter	15 picocuries per liter

*Values for microbiological and turbidity standards depend on qualifying conditions, but can generally be stated as 1 coliform organism per 100 milliliters and 1 turbidity unit, respectively, as monthly averages.

**Sum of bromodichloromethane, dibromochloromethane, bromoform, and chloroform; as average over one year.

***Excluding radon and uranium.

The U.S. Environmental Protection Agency has produced additional guidelines in the form of national secondary drinking water standards (Table 2). These specify non-enforceable limits that are considered desirable for color, odor, and a variety of water constituents.

The State and Federal primary and secondary drinking water standards apply to finished, or treated, water, as it is delivered in water supply systems. Some ground-water but very few surface-water sources will meet the drinking water standards prior to treatment.

A separate body of water quality standards exists for natural waters without considering treatment. These ambient water quality standards are tied to particular use classifications. For example, in Minnesota, waters whose classification includes industrial use have criteria of 500 milligrams per liter (mg/l) for hardness, 6.0-9.0 for pH, and 250 mg/l for chloride. As an interstate water, the Red River has more stringent industrial use criteria for hardness (250 mg/l) and chloride (100 mg/l) under the Minnesota standards. Tables 3 to 5 summarize the pertinent water quality standards for Minnesota and North Dakota.

C. COMMUNITY DESCRIPTIONS

Existing water facilities and water use for the study area communities are described below. Existing water use is characterized by "base year 1980" data as developed in the first step of the process of projecting future municipal demands (see section V). To improve the accuracy of the projections, the base year 1980 values are based on averages over several years. Therefore, actual values from 1980 utility records may vary slightly from those presented. Further discussion of the methodology and data used to develop base year water use is in Chapter V and Appendix A.

TABLE 2

ENVIRONMENTAL PROTECTION AGENCY
NATIONAL SECONDARY DRINKING WATER STANDARDS*

Chloride	250 milligrams per liter
Color	15 color units
Copper	1 milligram per liter
Foaming Agents	0.5 milligram per liter (as methylene blue active substances)
Iron	0.3 milligram per liter
Manganese	0.05 milligram per liter
Odor	3 threshold odor numbers
Sodium	No limit designated
Sulfate	250 milligrams per liter
Zinc	5 milligrams per liter

*Secondary standards represent national guidelines only; they are not standards unless they are specifically adopted by a State.

TABLE 3

NORTH DAKOTA STREAM WATER QUALITY STANDARDS SUMMARY
STANDARDS SPECIFIED FOR RED, SHEYENNE, AND MAPLE RIVERS

Substance or Characteristic	Limitation
CLASS I - SPECIFIED FOR RED RIVER:	
Ammonia, un-ionized (mg/l as N)*	0.02
Arsenic (mg/l)	0.05
Barium (mg/l)*	1.0
Boron (mg/l)*	0.5
Cadmium (mg/l)	0.01
Chloride (mg/l)*	100
Chromium (mg/l)	0.05
Copper (mg/l)	0.05
Cyanides (mg/l)	0.005
Lead (mg/l)*	0.05
Nitrate (mg/l as N)*	1.0
Phosphates (mg/l as P)*	0.1
Zinc (mg/l)	1.0
Selenium (mg/l)	0.01
Polychlorinated Biphenyls (ug/l)	0.001
Dissolved Oxygen (mg/l)	not less than 5.0
pH	7.0 - 8.5
Temperature (°F)	85 (maximum increase 5)
Fecal Coliform (per 100 ml)	200 (monthly geometric mean, May 1-September 30)
Sodium (milliequivalents/l)	50% of total cations
Phenols (mg/l)	0.01
Sulfate (mg/l)*	250
Total Chlorine Residual (mg/l)	0.01
Mercury (mg/l)	0.002

TABLE 3 (continued)

Substance or Characteristic	Limitation
CLASS IA - SPECIFIED FOR SHEYENNE RIVER:	
The physical and chemical criteria for Class IA shall be those for Class I, with the following exceptions:	
Chloride (mg/l)*	175
Sodium (milliequivalents/l)	60% of total cations
Sulfate (mg/l)*	450
CLASS II - SPECIFIED FOR MAPLE RIVER:	
The physical and chemical criteria for Class II shall be those for Class IA, with the following exceptions:	
Chloride (mg/l)*	250
Copper (mg/l)	0.1
Nitrate (mg/l as N)*	1.5
Phosphates (mg/l as P)*	0.2
Zinc (mg/l)	2.0
pH	6.0 - 9.0

*Dissolved fraction.

NOTE: Omitted here are extensive radiological criteria.

Standards for nitrate and phosphates are intended as guidelines; however, nitrate must not exceed 10 mg/l as N for any waters used as drinking water supply.

More restrictive criteria for copper, lead, and zinc may be developed to protect fish and aquatic life.

TABLE 4

MINNESOTA STREAM WATER QUALITY STANDARDS SUMMARY
STANDARDS SPECIFIED FOR RED RIVER (INTERSTATE)

Substance or Characteristic	Limit or Range
CLASS 1C (Domestic Consumption):	
Total Coliforms (per 100 ml)	1
Turbidity Value	25
Color Value	15
Threshold Odor Number	3
Methylene Blue Active Substance (mg/l)	0.5
Arsenic (mg/l)	0.01
Chloride (mg/l)	250
Copper (mg/l)	1
Carbon Chloroform Extract (mg/l)	0.2
Cyanides (mg/l)	0.01
Fluoride (mg/l)	1.5
Iron (mg/l)	0.3
Manganese (mg/l)	0.05
Nitrate (mg/l as NO_3)	45
Phenol (mg/l)	0.001
Sulfate (mg/l)	250
Total Dissolved Solids (mg/l)	500
Zinc (mg/l)	5
Barium (mg/l)	1
Cadmium (mg/l)	0.01

TABLE 4 (continued)

Substance or Characteristic	Limit or Range
Chromium, hexavalent (mg/l)	0.05
Lead (mg/l)	0.05
Selenium (mg/l)	0.01
Silver (mg/l)	0.05
CLASS 2C (Fisheries and Recreation):	
Those Class 2C criteria which are in addition to, or more restrictive than, any of the above are as follows:	
Dissolved Oxygen (mg/l)	Not less than 5
Temperature (°F)	5 above natural (maximum daily average 90)
Ammonia, un-ionized (mg/l as N)	0.04
Chromium (mg/l)	0.05
Copper (mg/l)	0.01
Oil (mg/l)	10
pH Value	6.5 - 9.0
Fecal Coliforms (per 100 ml)	200
Total Residual Chlorine (mg/l)	0.005
CLASS 3B (Industrial Consumption):	
Those Class 3B criteria which are in addition to, or more restrictive than, any of the above are as follows:	
Chloride (mg/l)	100
Hardness (mg/l)	250

TABLE 4 (continued)

Substance or Characteristic	Limit or Range
CLASS 3C (Industrial Consumption):	
Criteria above are more restrictive than those for Class 3C.	
CLASS 4A (Agriculture and Wildlife):	
Those Class 4A criteria which are in addition to, or more restrictive than, any of the above are as follows:	
Bicarbonate (milliequivalents/l)	5
Boron (mg/l)	0.5
pH Value	6.0 - 8.5
Specific Conductance (micromhos/cm)	1,000
Total Dissolved Salts (mg/l)	700
Sodium (millequivalents/l)	60% of total cations
Sulfate (mg/l)	.10 (for wild rice production)
CLASS 4B (Agriculture and Wildlife):	
Those Class 4B criteria which are in addition to, or more restrictive than, any of the above are as follows:	
Total Salinity (mg/l)	1,000
Unspecified Toxic Substances	None at harmful levels
CLASS 5 (Navigation and Waste Disposal):	
Those Class 5 criteria which are in addition to, or more restrictive than, any of the above are as follows:	
Hydrogen Sulfide (mg/l)	0.02

TABLE 4 (continued)

Substance or Characteristic	Limit or Range
CLASS 6 (Other Uses): No criteria specified.	

NOTE: Radiological criteria omitted.

TABLE 5

MINNESOTA STREAM WATER QUALITY STANDARDS SUMMARY
STANDARDS SPECIFIED FOR BUFFALO AND SOUTH BRANCH
BUFFALO RIVERS (INTRASTATE)

Substance or Characteristic	Limit or Range
CLASS 2B (Fisheries and Recreation):	
Dissolved Oxygen (mg/l)	Not less than 5
Temperature (°F)	5 above natural (maximum daily average 86)
Ammonia, un-ionized (mg/l as N)	0.04
Chromium (mg/l)	0.05
Copper (mg/l)	0.01
Cyanides (mg/l)	0.02
Oil (mg/l)	0.5
pH Value	6.5 - 9.0
Phenols (mg/l)	0.01
Turbidity Value	25
Fecal Coliforms (per 100 ml)	200
Total Residual Chlorine (mg/l)	0.005
CLASS 3C (Industrial Consumption):	
Those Class 3C criteria which are in addition to, or more restrictive than, any of the above are as follows:	
Chloride (mg/l)	250
Hardness (mg/l)	500

TABLE 5 (continued)

Substance or Characteristic	Limit or Range
CLASS 4A (Agriculture and Wildlife):	
Those Class 4A criteria which are in addition to, or more restrictive than, any of the above are as follows:	
Bicarbonate (milliequivalents/l)	5
Boron (mg/l)	0.5
pH Value	6.0 - 8.5
Specific Conductance (micromhos/cm)	1,000
Total Dissolved Salts (mg/l)	700
Sodium (milliequivalents/l)	60% of total cations
Sulfate (mg/l)	10 (for wild rice production)
CLASS 4B (Agriculture and Wildlife):	
Those Class 4B criteria which are in addition to, or more restrictive than, any of the above are as follows:	
Total Salinity (mg/l)	1,000
Unspecified Toxic Substances	None at harmful levels
CLASS 5 (Navigation and Waste Disposal):	
Those Class 5 criteria which are in addition to, or more restrictive than, any of the above are as follows:	
Hydrogen Sulfide (mg/l)	0.02
CLASS 6 (Other Uses): No criteria specified.	

NOTE: Radiological criteria omitted.

Buffalo and South Branch Buffalo Rivers have identical use classifications.

Water use is broken down into various sectors (residential, commercial, etc.) for the larger communities. Percentage breakdown comparisons are made with the following national municipal averages, as cited in a March 1981 publication of the Minnesota Department of Health:

Residential	40%
Commercial-Industrial	46%
Public and Unaccounted-for	14%

Comparisons are approximate, due to differences among communities in the manner of metering and reporting water use. Note that apartment buildings, other multiple family buildings, and mobile homes are usually included with commercial water users in utility records. This convention is followed in the present report. Wastewater treatment facilities are also briefly covered in the community descriptions.

1. Fargo

The Fargo Water Department service area includes the entire City of Fargo, North Dakota, including approximately 27 square miles and 61,000 people. Since 1912, the city has obtained its water entirely from the Red River. Recently, an enclosed pipeline and pump station has been constructed to bring Sheyenne River water to the filtration plant.

Fargo's water supply facilities are summarized in Table 6. Major municipal water supply facilities include raw water storage, river intake system, water treatment plant, and distribution facilities. Raw water is stored behind a low-head dam located near the juncture of Moorhead's 4th Avenue S.W. and the Red River. The existing structure has a crest at approximately 875 feet NGVD

TABLE 6

WATER FACILITIES DATA - FARGO

WATER SUPPLY SYSTEM

Surface Supply

Location	Pump Type	Pump Capacity(gpm)	Standby Power
Red River - (intake upstream at 13th Ave. So.)	submersible centrifugal	3 @ 3475 4 @ 2600 20825	None

Treated Water Storage

Location	Tank Type	Tank Capacity (Million Gallons)	Pump Capacity (gpm)
Treatment Plant	Clearwells	7.25	2 @ 6945 1 @ 4860 2 @ 3470 25690
Distribution System	Elevated Elevated	4 @ 0.5 1.0 10.25	

Raw Water Storage

Location	Tank Type	Capacity
Behind low-head dam on Red River at 2nd Street South	Reservoir behind low-head dam	Approximately 600 acre-feet

Treatment Plant

Location	Type	Rated Capacity(mgd)
Fargo	Lime-soda ash Softening with mixed media and filtration	25

and stores nearly 600 acre-feet (North Dakota State Water Commission, July 1983). Actual usable storage could vary greatly depending on sedimentation and evaporation. Estimated minimum total storages available during drought may range from 15 acre-feet to 200 acre-feet.

The water intake and treatment systems are designed to handle a maximum of 17,350 gallons per minute (gpm) (one 3,475 gpm pump is an auxiliary), or 25 million gallons per day (mgd). However, the recent Sheyenne River pipeline could raise the intake capacity from 25 mgd to approximately 41 mgd under emergency conditions if adequate streamflows were available.

The treatment plant uses a cold lime soda softening process. In the plant, the water is softened with lime soda, treated with activated carbon to reduce tastes and odors, disinfected, and filtered. Treated water is then stored within the plant in clearwells with a total capacity of 7.5 million gallons.

Residue from the treatment process is dried and landfilled. Distribution facilities include high service pumps that move treated water from the clearwells through the distribution system and into the five elevated storage tanks.

The city has a declining block rate form that includes a minimum demand charge based on the diameter of the meter connection. Conservation is encouraged by an additional charge for water-cooled air conditioning systems that do not re-use water. Residential customers are billed quarterly, and commercial customers receive monthly statements. Since 1971, water rates have risen four times: 22 perent in 1972, 18.5 percent in 1975, 30 percent in 1977, and 15 percent in 1980 (Fargo Forum, March 6, 1983).

In addition to the Sheyenne diversion, the city is also considering development of the Hickson or West Fargo South Aquifer. This project would involve development of a well field 5 or 6 miles east of Kindred in southeastern Cass County and a pipeline to the treatment plant, possibly tying into the Sheyenne diversion pipeline 3 miles north of Horace.

The Fargo wastewater treatment plant uses primary clarification, trickling filtration, final clarification, and waste stabilization. The design capacity is 9 mgd on an annual average basis and 18 mgd under peak conditions. The plant handles return flows from municipal potable water customers plus minor amounts of self-served industrial effluent from the Cass-Clay Creamery. In 1982, the plant treated an average of approximately 7.7 mgd, with a peak flow of 15.6 mgd.

Fargo's municipal treated water use between 1977 and 1981 averaged 8.8 mgd or approximately 149 gallons per capita per day based on 1980 population figures. Maximum day use over the same period approached 23 mgd. In order to examine municipal water use in greater detail, total use is disaggregated or partitioned among the major water consuming sectors, including residential, commercial, industrial, and public and unaccounted-for. Public and unaccounted-for use includes water used in public buildings, hydrant flushing, irrigation of city parks and water unaccounted for due to breakage or meter misregistration. The following breakdown of total water use (excluding water treatment plant process water) is representative of recent use, though relative composition varies from year to year:

Residential	32%
Commercial	35%
Industrial	5%
Public and Unaccounted-for	28%

The percentages of residential use and combined commercial-industrial use are slightly lower than national municipal averages. However, Fargo's public and unaccounted-for use is double the national average. This disparity may be partially a result of the large number of public buildings served for a city of its size and the large amount of pipeline breakage.

Absolute values for each sector's use in the base year 1980 are shown in Table 7. The maximum day demand shown is calculated in aggregate based on historical municipal data. Maximum day demands for individual sectors are given in Tables 8 and 9 and Appendix A. The total of all sector maximum day demands would not equal the historically derived aggregate value in Table 7 because the individual-sector maximums do not all occur simultaneously.

Note that process water use for water treatment is given in Table 7 as a maximum estimate. The estimate may be affected by meter error, and water utility personnel believe that actual process water use is substantially less than shown in Table 7. In addition, most of the process water is recycled at the Fargo water treatment plant.

The commercial and industrial sectors can be further divided into their component parts. Tables 8 and 9 show the different components of these sectors in the base year 1980. The demand of each component is based on a quantifiable water-use-related parameter and a use-per-parameter coefficient.

TABLE 7

BASE YEAR WATER DEMANDS -- FARGO
(million gallons per day)

	Year 1980 Average Annual	Year 1980 Maximum Day
METERED USE		
Residential	2.96	
Commercial	3.28	
Industrial	0.50	
Subtotal	6.74	
UNMETERED USE		
Unaccounted-for and Public	2.56	
Subtotal	9.30	21.20
Water Treatment Process Water	0.93	0.93
MUNICIPAL TOTAL	10.23	22.13

NOTE: Maximum day prediction based on historic relation between average annual use (excluding water treatment process water) and maximum day.

Unaccounted-for water use estimated from historical data to be 38 percent of metered use.

Water treatment process water estimated from historical water utility pumping records to be 10 percent of other total use. Though not a consumptive use, process water represents a significant demand for clean river water that is required for safe operation of the facility. For this reason, Fargo's process water demand is included in this table.

TABLE 8

BASE YEAR COMMERCIAL WATER USE DATA - FARGO

Type of Commercial Establishment	Parameter Units	Number of Units	YEAR 1980 CALCULATED WATER DEMAND (gallons per day) Average Annual	Maximum Day	Peak Hour
Portion 1					
Hotels	sq. ft.	47,900	12,262	14,083	20,741
Motels	sq. ft.	913,700	204,669	421,216	1,416,235
Barber Shops	barber chair	35	1,911	2,811	13,615
Beauty Shops	station	151	40,619	49,528	161,570
Restaurants	seat	9,550	231,110	796,470	1,594,850
Night Clubs	persons served	5,800	7,714	7,714	7,714
*Hospitals	bed	1,020	289,680	461,040	763,980
Nursing Homes	bed	705	93,765	102,930	298,920
*Medical Offices	sq. ft.	180,000	24,840	66,780	199,800
*Laundries	sq. ft.	24,894	117,000	156,334	831,460
*Laundromats	sq. ft.	14,000	30,380	40,600	215,600
*Bus-Rail Depots	sq. ft.	18,000	18,000	35,100	135,000
*Car Washes	sq. ft.	17,000	40,460	87,210	266,900
Churches	members	20,000	2,760	17,240	94,000
*Clubs	members	450	9,990	9,990	9,990
Bowling Alleys	alleys	52	6,916	6,916	6,916
New Office Buildings	sq. ft.	256,000	23,808	44,288	133,376
Old Office Buildings	sq. ft.	821,100	116,596	216,770	290,669
*YMCA	members	750	15,200	15,200	15,200
Service Stations	office sq. ft.	16,400	4,116	9,676	80,196
Sub-Total - Portion 1			1,291,796	2,561,896	6,556,732

TABLE 8 (continued)

BASE YEAR COMMERCIAL WATER USE DATA - FARGO

Type of Commercial Establishment	Parameter Units	Number of Units	YEAR 1980 CALCULATED WATER DEMAND (gallons per day) Average Annual	Maximum Day	Peak Hour
Portion 2					
*Multiple Family Homes	occupied units	10,755	1,129,275	1,693,912	9,292,320
*Mobile Homes	number of units	1,419	251,163	376,744	1,634,688
Retail Space	sales sq. ft.	1,197,630	126,949	184,435	324,558
Elementary Schools	students	6,665	35,858	64,517	327,252
High Schools	students	3,612	23,948	70,795	437,052
*Colleges	on-campus students	2,178	422,532	455,202	997,524
Sub-Total - Portion 2			1,989,725	2,845,605	13,013,394
TOTAL (Portion 1 and Portion 2)			3,281,521	5,407,501	19,570,126
TOTAL in million gallons per day			3.28	5.41	19.57

NOTE: Calculated water demand based on use-per-unit coefficients of Hittman and Associates (1969).

A * denotes commercial establishment types which have water use-per-unit coefficients derived from utility records and other sources.

Motel values include Doublewood Inn which was completed just after 1980.

Restaurant values do not include restaurants in motels or hotels.

TABLE 9

BASE YEAR INDUSTRIAL WATER USE DATA - FARGO

S.I.C. Code	Industry Description	Number of Employees	YEAR 1980 CALCULATED WATER DEMAND (gallons per day) Average Annual	Maximum Day	Peak Hour
202	*Dairies	249	32,877	32,877	36,165
203	*Specialty Foods	249	32,877	32,877	36,165
204	*Grain Mills	61	29,768	29,768	32,745
205	Bakery Products	157	34,635	34,635	38,098
208	*Beverages	86	98,630	98,630	108,493
230	Wholesale Apparel Industry	12	240	240	264
243	Millwork	10	3,160	3,160	3,476
251	Home Furniture	50	6,109	6,109	6,720
264	Paper Products	12	5,229	5,229	5,752
265	Paperboard Boxes	12	1,858	1,858	2,044
270	Wholesale Print Industry	397	18,195	18,195	20,014
282	*Plastic	25	36,789	36,789	40,468
306	**Rubber Products	50	12,500	12,500	13,750
307	Plastic Products	34	17,952	17,952	19,747
327	Cement	111	39,294	39,294	43,223
328	Cut Stone	3	1,604	1,604	1,764
343	Plumbing	25	10,289	10,289	11,318
344	Structure Metal	271	16,102	16,102	17,712
347	**Metal Services	12	12,500	12,500	13,750

TABLE 9 (continued)

BASE YEAR INDUSTRIAL WATER USE DATA - FARGO

			YEAR 1980 CALCULATED WATER DEMAND (gallons per day)		
S.I.C. Code	Industry Description	Number of Employees	Average Annual	Maximum Day	Peak Hour
352	*Farm Machinery	709	24,815	24,815	27,296
353	Construction Equipment	4	873	873	960
355	Special Industrial Equipment	4	1,162	1,162	1,278
359	Misc. Machine Work	69	16,491	16,491	18,140
362	Electric Industrial Apparatus	26	8,736	8,736	9,610
369	Electric Products	34	13,362	13,362	14,698
371	Motor Vehicles	29	9,222	9,222	10,144
384	Medical Instrument	9	4,554	4,554	5,009
399	Misc. Manufacturing	25	6,450	6,450	7,095
INDUSTRIAL TOTAL:		2,735	496,273	496,273	545,898
TOTAL in million gallons per day:			0.50	0.50	0.55

NOTE: Peak hour estimated to be 10% greater than annual average use.

One star (*) denotes industrial categories which have use-per-unit coefficients derived from utility records and other sources.

Two stars (**) denote that no actual use information is available so maximum possible use is assumed (12,500 gallons per day per business water meter).

Employment data from Fargo-Moorhead Directory of Manufacturers and Fargo Job Service.

2. Moorhead

The Moorhead water utility serves the entire City of Moorhead, Minnesota, plus some adjacent developments. In 1980, the city included 8.7 square miles and almost 30,000 people. In the past, Moorhead has expanded to new supply sources several times. In 1947, the city added two new wells in the Buffalo Aquifer to its two existing wells in the Moorhead Aquifer. Expansion was again required in the early 1960's due to declining water levels and increased mineralization of Buffalo Aquifer water. The Red River has remained the primary source since that time, supplying approximately 60 percent of the city's water.

Moorhead's existing water facilities are summarized in Table 10. The peak design capacity of the entire system is approximately 9 mgd. With all pumps in service, the city has a total daily well production of approximately 4.38 mgd and a river supply capacity of 5 mgd. With the largest pump out of service, the maximum daily river intake yield falls to 3.78 mgd and the total municipal yield to 8.16 mgd. The Moorhead intake shares the reservoir pooled behind Fargo's low-head dam with the City of Fargo. This reservoir is discussed further within the section on Fargo's existing facilities.

The Moorhead water treatment plant is composed of two semi-independent facilities with a combined peak capacity of 9 mgd. Both plants use a lime/soda ash softening process to purify the water. This process removes hardness, turbidity, odor, taste, color, and bacteria.

The city's water distribution system is entirely metered. The master meter is located at the water treatment plant. All high service pumping is done from there with the exception of the 1,600 gpm pump at the 20th Avenue storage tank. The total high service capacity is 23.5 mgd. There are six treated water storage tanks, including the water treatment plant's clearwells, for a total of 4.84 million gallons of storage.

TABLE 10

WATER FACILITIES DATA - MOORHEAD
WATER SUPPLY SYSTEM

Groundwater Supply

Location	Pump Type	Pump Capacity (gpm)	Standby Power
Buffalo Aquifer			
Well #8	Turbine	1150*	Gas Engine
Well #9	Turbine	1150*	None
Well #10	Turbine	1900*	Gas Engine
Moorhead Aquifer			
Well #6	Turbine	500	None
Well #6A	Turbine	540	Gas Engine
		3040 (Considering transmission limitation for Buffalo aquifer)	

Note: *Maximum short duration yield for the Buffalo Aquifer well field is 2.88 mgd (2000 gpm), due to limited transmission line capacities.

Surface Supply

Location	Pump Type	Pump Capacity (gpm)
On Red River (Above 4th Ave. S.W. low-head dam)	Centrifugal	Actual combined rate with 2 pumps under best conditions is 3470 gpm. (It is only 2626 gpm with 1 pump out of service)

Treated Water Storage

Location	Tank Type	Tank Capacity (Million Gallons)	Pump Capacity (gpm)
Treatment Plant	Clearwells	0.10	2 at 2000
	Underground	2.44	Actual combined rate with 2 pumps is 7500 gpm
	Ground Level	1.00	2 pumps: 1 at 2800, 1 at 3250, used alternately
20th St. & 70th Ave. So.	Underground	0.50	
12th St. & 1st Ave. No.	Elevated	0.50	
Elm St. S. & 6th Ave.	Elevated	0.30	
		4.84	

TABLE 10 (continued)

WATER FACILITIES DATA - MOORHEAD

WATER SUPPLY SYSTEM

Raw Water Storage

Location	Type	Capacity (Million Gallons)	Pumps (gpm)
Buffalo Well Field	Ground tank	0.005	2000
Red River low-head dam	Reservoir behind low-head dam	Approximately 600 acre-feet	(See Surface Supply)

Treatment Plant

Location	Type	Rated Capacity(mgd)
Moorhead	Lime-soda ash Softening with dual media and rapid sand filtration	9

The Moorhead Public Service Department uses a declining block rate form plus a minimum demand charge. The minimum demand charge varies with meter diameter. Customers outside the city limits are charged higher prices for water use beyond the minimum. All customers are billed monthly.

At this time, the city has no planned water facility expansion or major modifications.

The present municipal wastewater system is a completely new facility, technically termed a composite secondary treatment plant. It uses an oxygen-activated sludge system designed to meet the high demands of agricultural processing wastes. The system can handle a capacity of 25,000 pounds per day of biochemical oxygen demand (BOD). It also has a trickling filter treatment system. The new average daily treatment capacity is 6 mgd and the peak capacity is 9 mgd. The system handles effluent from Dilworth as well as Moorhead. Current average annual influent flows are approximately 4.25 mgd, including 0.8 mgd industrial effluent, 0.6 mgd inflow and infiltration, and less than 0.001 mgd of trucked in septage. The plant discharges continually into the Red River.

Moorhead's municipal water use between 1977 and 1981 averaged 3.63 mgd. Maximum day use over the same period was more than 8 mgd. Total municipal water use can be disaggregated among the major user sectors. The following breakdown of the total municipal use is representative of recent use, though relative composition varies from year to year:

Residential	38%
Commercial	27%
Industrial	27%
Public and Unaccounted-for	8%

Public and unaccounted-for use is approximately half the national average.

Absolute values for each sector's use in the base year 1980 are shown in Table 11. The maximum day demand shown is calculated in aggregate based on historical municipal data, as discussed for Fargo.

The base year commercial and industrial water demands are divided into their component parts in Tables 12 and 13. The demand of each component is based on a quantifiable water use-related parameter and a use-per-parameter coefficient. See Chapter V for a more detailed discussion of these demands.

3. West Fargo

The West Fargo Water Department serves the entire area of the City of West Fargo, North Dakota. In 1980, the city included 6.2 square miles and 10,080 people. The city presently obtains all its water from six wells in the West Fargo Aquifer. Historically, when the city has anticipated a water shortage, they have been able to drill a new well near the area of expansion. In 1983, the city completed development of a 920-gpm well in the southeastern portion of town. No further expansion is planned at this time.

The city's existing water facilities are summarized in Table 14. At full capacity, the system can supply 3.92 mgd. Firm capacity, with the largest pump out of service, is approximately 2.52 mgd. The static water levels in the area's wells have historically been declining, indicating that average recharge and, therefore, safe yield in the developed portion of the aquifer are probably being exceeded.

TABLE 11

BASE YEAR WATER DEMANDS - MOORHEAD
(million gallons per day)

	Year 1980	
	Average Annual	Maximum Day
METERED USE:		
Residential	1.66	
Commercial	1.21	
Industrial	1.18	
Subtotal:	4.05	
UNMETERED USE:		
Unaccounted-for and Public	0.36	
MUNICIPAL TOTAL:	4.41	8.82

NOTE: Maximum day prediction based on historic relation between average annual day and maximum day.

Unaccounted-for and public use estimated from historical data to be approximately 9 percent of metered use.

Water treatment process water represents negligible consumptive use in Moorhead as a result of conservation practices in the water treatment plant.

TABLE 12

BASE YEAR COMMERCIAL WATER USE DATA - MOORHEAD

Type of Commercial Establishment	Parameter Units	Number of Units	YEAR 1980 CALCULATED WATER DEMAND (gallons per day) Average Annual	Maximum Day	Peak Hour
Portion 1					
*Motels	sq. ft.	342,400	58,208	119,840	404,032
Barber Shops	barber chair	9	491	723	3,501
Beauty Shops	stations	73	19,637	23,944	78,110
Restaurants	seats	4,125	99,825	344,025	688,875
Night Clubs	persons served	1,787	2,377	2,377	2,377
*Hospitals	beds	155	24,490	39,060	64,480
Nursing Homes	beds	340	45,220	49,640	144,160
Medical Offices	sq. ft.	36,520	22,569	60,623	181,504
*Laundromats	sq. ft.	2,200	4,770	6,380	33,900
Bus-Rail Depots	sq. ft.	300	999	1,950	7,500
*Car Washes	sq. ft.	13,600	27,472	59,160	180,880
Churches	members	10,000	1,380	8,620	47,000
Bowling Alleys	alleys	40	5,320	5,320	5,320
New Office Buildings	sq. ft.	38,800	3,608	6,712	20,215
Old Office Buildings	sq. ft.	265,200	37,658	70,013	93,881
*YMCA-YWCA	members	3,000	3,363	3,363	3,363
Service Station	office sq. ft.	6,400	1,606	3,776	31,296
*Moorhead Power Plant	1980 use gallons/day	1	14,225	14,225	15,648
*Moorhead Sports Center	1980 use gallons/day	1	6,251	6,251	6,251
Sub-Total - Portion 1			379,469	826,002	2,012,293

TABLE 12 (continued)

BASE YEAR COMMERCIAL WATER USE DATA - MOORHEAD

Type of Commercial Establishment	Parameter Units	Number of Units	YEAR 1980 CALCULATED WATER DEMAND (gallons per day)		
			Average Annual	Maximum Day	Peak Hour
Portion 2					
*Multiple Family Homes	number of units	3,915	411,075	616,612	3,382,560
*Mobile Homes	number of units	395	69,915	104,872	455,040
Retail	sales Sq. Ft.	450,000	47,700	69,300	121,950
Schools:					
Elementary	students	3,156	16,979	30,550	154,960
High	students	1,861	12,338	36,476	225,181
*Colleges & Technical Schools	on-campus students	4,258	272,512	293,802	642,958
Sub-Total - Portion 2			830,519	1,151,612	4,982,649
TOTAL (Portion 1 and Portion 2)			1,209,988	1,977,614	6,994,942
TOTAL in million gallons per day			1.21	1.98	6.99

NOTE: Calculated water demand based on use-per-unit coefficients of Hittman and Associates (1969).

A * denotes commercial establishment types which have water use-per-unit coefficients derived from utility records and other sources.

TABLE 13

BASE YEAR INDUSTRIAL WATER USE DATA - MOORHEAD

S.I.C. Code	Industry Description	Year 1980 Employment	YEAR 1980 CALCULATED WATER DEMAND (gallons per day) Average Annual	Maximum Day	Peak Hour
206	*Sugar Production and Research	700	352,800	352,800	388,080
208	*Beverages	62	43,462	43,462	47,808
208	*Malting Plant	48	747,120	747,120	821,832
251	Home Furniture	14	1,710	1,710	1,881
270	Wholesale Print Industry	25	375	375	412
327	*Cement	100	5,840	5,840	6,424
344	Structural Metal	33	10,556	10,556	11,612
359	Misc. Machining	3	717	717	789
369	Electrical Products	15	5,899	5,899	6,489
371	Motor Vehicles	15	4,773	4,773	5,250
373	Boat Building	12	1,993	1,993	2,192
398	*Administrative/Auxiliary Staff	365	3,650	3,650	4,015
399	Misc. Manufacturing	7	1,808	1,808	1,989
INDUSTRIAL TOTAL:		1,399	1,180,703	1,180,703	1,298,773
TOTAL in million gallons per day			1.18	1.18	1.30

NOTE: Unless otherwise indicated, water demand shown is calculated as product of number of employees and a water use per employee coefficient from Hittman and Associates (1969).

One star (*) denotes industrial categories which have use-per-unit coefficients derived from utility records and other sources.

Peak hour estimated to be 10% greater than average annual use.

Employment data from Fargo-Moorhead Directory of Manufacturers and Moorhead Job Service.

TABLE 14

WATER FACILITIES DATA - WEST FARGO

WATER SUPPLY SYSTEM

Groundwater Supply

Location	Pump Type	Capacity(gpm)	Standby Power
West Fargo Aquifer			(6) Portable Generators
Well #3	Turbine	60	
Well #4	Turbine	300	
Well #5	Turbine	470	
Well #6	Turbine	970	
Well #7	Turbine	920	
		2720	

Treated Water Storage

Location	Tank Type	Capacity (Million Gallons)
12th Ave. & 4th Str.	Elevated	0.5
2nd Ave. & 8th Str.	Elevated	0.5
		1.0

Treatment

Chlorination and fluoridation at well head

Water treatment capacity is limited to the maximum well pumping rates since the only treatment is disinfection and fluoridation at the well house. There are 1.0 million gallons of treated water storage in the city's two 500,000-gallon elevated tanks.

The water utility uses a declining block rate form with a minimum demand charge. The utility also reserves the right to restrict or prohibit unnecessary use of water through public notice.

The West Fargo wastewater treatment plant uses a stabilization pond system with rapid aeration in the primary cells. The design capacity is 1.33 mgd, though an expansion project is under way to add new lagoons that will increase the design capacity by approximately 50 percent. The plant handles approximately 0.7 mgd of wastewater from the city, including combined flows from a small portion of the city. In addition, the city treats 0.39 mgd of high-BOD effluent from the Held Beef slaughterhouse. When the plant's expansion is complete, it is planned to handle wastewater from the City of Riverside and the local Cargill sunflower processing plant. Infiltration from ground water has increased the average volume of sewered water by as much as 1.5 mgd. The existing plant discharges to the Sheyenne River in the spring and fall with discharge volumes ranging from 1 to 3 mgd.

West Fargo average annual municipal water use between 1977 and 1981 averaged 0.78 mgd. Maximum day use over the same period was more than 2.4 mgd. The following disaggregation is representative of recent years, though relative composition may vary slightly from year to year:

Residential	58%
Commercial	31%
Industrial	2%
Unaccounted-for and Public	9%

West Fargo's residential water use is significantly greater and industrial use significantly less than the national average. This tends to confirm West Fargo's bedroom community status for the larger portion of the urban area. Unaccounted-for and public use is approximately two-thirds of the national average.

Absolute values for each sector's use in the base year 1980 are shown in Table 15. The maximum day value shown is calculated in aggregate based on historical municipal data, as discussed for Fargo.

The disaggregated base year commercial and industrial water demands are divided into their component parts in Tables 16 and 17. The demand of each component is based on a quantifiable water use-related parameter and a use-per-parameter unit coefficient. A more detailed discussion of these demands is in Chapter V.

4. Dilworth

The City of Dilworth, Minnesota, is adjacent to the eastern border of Moorhead on U.S. Trunk Highway 10. The water utility serves all properties within the corporate limits. The 1980 census indicates that approximately 2,580 people live within the 1.7-square mile service area.

TABLE 15

BASE YEAR WATER DEMANDS - WEST FARGO
(million gallons per day)

	Year 1980	
	Average Annual	Maximum Day
METERED USE:		
Residential	0.50	
Commercial	0.27	
Industrial	0.02	
Subtotal:	0.79	
UNMETERED USE:		
Unaccounted-for and Public	0.08	
MUNICIPAL TOTAL:	0.87	2.11

NOTE: Maximum day prediction based on historic relation between average annual day and maximum day.

Unaccounted-for and public use estimated from historical data to be approximately 10 percent of metered use.

TABLE 16

BASE YEAR COMMERCIAL WATER USE DATA - WEST FARGO

Type of Commercial Establishment	Units	Number of Units	YEAR 1980 CALCULATED WATER DEMAND (gallons per day) Average Annual	Maximum Day	Peak Hour
Portion 1					
Motel	sq. ft.	66,700	14,940	30,749	103,385
Restaurants	seats	500	12,100	41,700	83,500
*Medical Offices	sq. ft.	6,800	394	1,061	3,169
*Office Buildings	sq. ft.	89,800	10,596	19,700	59,400
*Laundromat	sq. ft.	2,200	1,644	2,196	11,660
Retail	sales sq. ft.	90,000	9,540	13,860	24,390
Service Stations	sq. ft.	3,600	904	2,124	17,604
*Fairgrounds		1	315	16,428	16,428
Sub-Total - Portion 1			50,433	127,818	319,536

TABLE 16 (continued)

BASE YEAR COMMERCIAL WATER USE DATA - WEST FARGO

Type of Commercial Establishment	Parameter Units	Number of Units	YEAR 1980 CALCULATED WATER DEMAND (gallons per day) Average Annual	Maximum Day	Peak Hour
Portion 2:					
*Multiple Family Housing	number of occupied units	1,163	122,115	183,172	1,004,832
*Mobile Homes	number of units	442	78,234	117,351	509,184
Schools:					
Elementary	students	2,541	13,670	24,597	124,763
High	students	854	5,662	16,738	103,334
Sub-Total - Portion 2			219,681	341,858	1,742,113
TOTAL (Portion 1 and Portion 2)			270,114	469,676	2,061,649
TOTAL in million gallons per day			0.27	0.47	2.06

NOTE: Calculated water demand based on use-per-unit coefficients of Hittman and Associates (1969).

One star (*) denotes commercial establishment types which have water use-per-unit coefficients derived from utility records and other sources.

TABLE 17

BASE YEAR INDUSTRIAL WATER USE DATA - WEST FARGO

S.I.C. Code	Industry Description	Year 1980 Employment	YEAR 1980 CALCULATED WATER DEMAND (gallons per day) Average Annual	Maximum Day	Peak Hour
201	*Meat Products	20	6,575	6,575	7,232
327	Cement	2	708	708	779
344	Structural Metal	3	178	178	196
349	Fabricated Metal	9	2,439	2,439	2,683
359	Misc. Machining	30	7,170	7,170	7,887
371	*Motor Vehicles	110	7,232	7,232	7,955
	INDUSTRIAL TOTAL:	174	24,302	24,302	26,732
	TOTAL in million gallons per day:		0.02	0.02	0.03

NOTE: Peak hour estimated to be 10% greater than annual average use.

One star (*) denotes industrial categories which have use-per-unit coefficients derived from utility records and other sources.

Employment data from Fargo-Moorhead Directory of Manufacturers and Fargo Job Service.

Dilworth's municipal facilities are summarized in Table 18. The city obtains its water from the Kragnes Aquifer via three wells located in the City Park near the intersection of 4th Street and 1st Avenue N.E. The wells range in depth from 155 to 175 feet. The yield of these wells is limited by a well interference problem which takes the smallest well out of service under peak pumping conditions. The resulting maximum daily production is approximately 1.04 mgd, and the average daily production is limited to 0.20 mgd (Larson-Peterson and Associates, 1981). With the largest well out of service, maximum daily production becomes approximately 0.50 mgd (Minnesota Department of Health, 1981). Preliminary investigations have recently been completed for two additional 100-gpm wells.

Water treatment includes chlorination, fluoridation, and corrosion stabilization at the well house. There are 100,000 gallons of elevated treated water storage available to help meet emergency needs. The distribution system consists of 57,000 feet of primarily 6-inch PVC and 8-inch PVC-asbestos cement pipe replaced or constructed since 1966 (Larson-Peterson and Associates, 1981).

The Dilworth water system is entirely metered and average annual per capita water use ranges from 80 gallons per day (gpd) in 1980 to 70 gpd in 1981. Municipal peak daily use is approximately 200 percent of average daily use. The city's water system almost exclusively serves residential users. Of the total 933 service connections, 903 are residential. Minnesota Department of Health records indicate that residential water use accounts for 82 percent of total water use.

TABLE 18

WATER FACILITIES DATA - DILWORTH

WATER SUPPLY SYSTEM

Groundwater Supply

Location	Pump Type	Capacity (gpm)	Standby Power
Kragnes Aquifer	Turbine	270	None
	Turbine	350	
	Submersible	375	
		725*	

*Under peak pumping conditions, smallest well (270 gpm) cannot be used because of well interference problem.

Planned Expansion in 1984

Undesignated Aquifer	Submersible	100
	Turbine	100
		925

Treated Water Storage

Location	Tank Type	Capacity (Million Gallons)
Dilworth	100' elevated	0.10

Treatment

Chlorination, fluoridation and corrosion stabilization at well head

There are approximately 30 commercial connections. Collectively, these account for 16 percent of the total average annual use. Larger commercial users include mobile home parks, apartment houses, the public school, and the Burlington Northern Railroad switching facilities and repair shop. The remaining two percent of the total average annual use is composed of public and unaccounted-for use (Minnesota Department of Health, 1981).

The city has a routine physical and mechanical inspection program for the water supply system. Emergency conservation is encouraged by public ordinances, including a summer lawn sprinkling ban (Minnesota Department of Health, 1981).

Prior to 1981, Dilworth had a cost-of-service pricing philosophy and a declining block rate form. In January 1981, a straight rate or single block rate form with a minimum demand charge was adopted.

Dilworth uses Moorhead's wastewater treatment facilities, which discharge into the Red River. Estimates of average flows were not provided by city officials.

5. Glyndon

Glyndon, Minnesota, is a community of approximately 880 people 7 miles east of Moorhead on U.S. Trunk Highway 10. The city obtains its water from two wells in the Buffalo Aquifer with a maximum yield of 520,000 gpd. The yield is half of this amount with one pump out of service. Glyndon has a small water treatment plant with five sand pressure filters. The plant disinfects, aerates, filters, and fluoridates the city's water. The distribution system has 50,000 gallons of elevated storage.

Wastewater from Glyndon is pumped into a 7-acre primary lagoon. From there it enters a secondary 3-acre lagoon. Overflow is constant from the secondary lagoon. The overflow enters a creek that discharges to the Buffalo River. According to 1980 and 1981 records, about 78 percent of withdrawals are returned to the lagoons. The wastewater facility has a capacity of 60,000 gpd. The wastewater treatment system is presently overloaded. The actual flow has exceeded the design flow since 1979 by a minimum of 0.02 mgd.

The utility has a flat rate pricing system since both residential and commercial customers are unmetered. Total municipal water use in 1980 was approximately 96,000 gpd, or 109 gpd per capita (E. A. Hickok and Associates, 1982). The city estimates that 90 percent of this use is residential and that the remaining 10 percent is commercial use.

Maximum daily production is approximately 105,000 gallons. A municipal emergency water supply program is available to conserve water during a drought. This plan includes the use of water-saving devices and ordinances enabling measures like sprinkling bans. The city's routine maintenance inspections and leak detection program also help to conserve water.

6. Sabin

Sabin, Minnesota, is a community of approximately 630 people 5 miles southeast of Moorhead on County State Aid Highway 52. The city obtains its water from one unmetered well in the Buffalo Aquifer, with a maximum yield of 360,000 gpd. Since the water system is unmetered, a flat charge water rate form is used for all customers. Water treatment consists of aeration and filtration at the well head.

The distribution system has 140 service connections and 75,000 gallons of elevated storage. The distribution system is composed of approximately 10,000 feet of cast iron pipe that has seriously deteriorated because of reactions with the alkaline soils. Funding for planned improvements is still unavailable.

The city operates a wastewater stabilization lagoon that discharges twice annually in June and October to the Red River via County Ditch No. 32. Its design capacity is 98,000 gpd, and average annual discharge is approximately 30,000 gpd.

Estimates of existing water use are based on water use information from nearby communities and known wastewater flows. Average annual use is estimated to be 57,000 gpd, or 90 gpd per capita (E. A. Hickok and Associates, 1982). Maximum daily use is probably near 200 percent of average annual use. The city estimates that 90 percent of its total consumption is residential and 10 percent commercial.

7. Harwood

Harwood, North Dakota, is 3 miles northwest of Fargo on Interstate Highway 29. Harwood is served by two 200-foot deep wells in an unnamed aquifer. The second well was added in 1982. There is a third small 20-gpm well, but it is not used under normal operating conditions. The maximum combined production of the two larger wells is approximately 576,000 gpd. The service area includes residents outside the corporate boundaries. The total number of customers is approximately 540. Water treatment consists of disinfection at the well head.

The distribution system had 160 metered connections in 1980. Though there is no treated water storage, there are 14 small pressure tanks to maintain pressure in the distribution lines. The city uses a declining block rate form with a minimum demand charge.

The City of Harwood is presently in need of an additional 1-acre lagoon for wastewater treatment. An EPA construction grant plan has been proposed for a combined wastewater treatment plant to serve both Harwood and Reile's Acres. This plan would involve construction of a new facility and abandonment of Harwood's existing facilities.

Municipal water use in 1980 was approximately 43,000 gpd (E. A. Hickok and Associates, 1982). Maximum day water use is estimated to be 200 percent of the annual average demand.

8. Horace

Horace, North Dakota, is a community of 497 people 6 miles south of West Fargo. Horace recently formed a municipal supply system using water from four wells in an unnamed aquifer. These wells have a combined maximum production of 209,000 gpd.

The distribution system has 174 metered service connections and 108,000 gallons of treated water storage. The utility uses a declining block rate form with a minimum demand charge (North Dakota State Department of Health, 1983).

Horace operates a wastewater stabilization pond system that discharges into the Red River via a county drain. Presently, two cells are being added which will increase the design capacity to 60,000 gpd. This expansion is based on a daily wastewater flow of 84 gallons per capita (North Dakota State Department of Health, 1983).

The 1980 water use was approximately 29,000 gpd, or a per capita daily use of 59 gallons (E. A. Hickok and Associates, 1982). Maximum daily use is estimated to be 200 percent of the annual average use, or 58,000 gpd.

9. Riverside

Riverside, North Dakota, is immediately north of West Fargo. In 1980, the city had a population of 465. Water is obtained from one well in the West Fargo Aquifer and chlorinated at the well house. The maximum daily yield is 396,000 gpd. The distribution system has 154 residential and 28 commercial metered service connections. Customers are billed using a declining block rate form with a minimum demand charge. The distribution system also includes 75,000 gallons of treated water storage. Riverside's wastewater has been treated by West Fargo's plant since the summer of 1983.

Municipal average daily water use has recently increased to almost 39,000 gpd, though the average use over the last 7 years has been only 24,000 gpd (E. A. Hickok and Associates, 1982). The maximum monthly use in 1982 was more than 54,000 gpd. Large commercial users include a Cargill sunflower processing plant and several other agricultural processors. In some months, the commercial customers use more than 50 percent of the city's treated water.

10. Mapleton

Mapleton, North Dakota, is 8 miles west of Fargo on Interstate Trunk Highway 94. In 1980, the population was 307. The city has purchased treated water in bulk from the Cass Rural Water Users Association (CRWUA) since 1977. The old water supply is still functional, and the 50,000-gallon storage tank is still

used; however, the water quality in the old well is very poor. The city's present CRWUA maximum allotment is 50,000 gpd. The municipal distribution system provides metered service to 97 individual connections. The city uses a declining block rate form with a minimum demand charge.

Mapleton is presently served by a four-cell wastewater stabilization pond system. The system has a storage capacity of 49.6 acre-feet (16.2 million gallons). The estimated average inflow is 21,000 gpd, based on a contribution of 70 gallons per day per capita.

The 1980 municipal use was approximately 25,000 gpd, or 80 gallons per capita per day (E. A. Hickok and Associates, 1982). The 1980 maximum monthly demand was 32,000 gpd in June.

11. Reile's Acres

Reile's Acres, North Dakota, is an incorporated community of 191 people 3 miles north of West Fargo. The city's water supplies are obtained from homeowner wells. Approximately 10 percent of the 51 homes obtain water via individual contracts with the CRWUA. Individual septic systems are used to dispose of wastewater. Currently, daily water use is estimated to be 13,000 gallons, or 70 gallons per capita (E. A. Hickok and Associates, 1982).

12. Frontier

Frontier, North Dakota, is an incorporated community of approximately 152 people located three miles south of Fargo along Interstate Trunk Highway 29. The 47 homes receive treated water from the CRWUA on an individual basis, and individual septic systems are used for disposal of wastewater. As a result of local drainfield failures, a regional planning agency has investigated cluster

collection and treatment systems for this and other smaller area communities (Lake Agassiz Regional Planning Commission, 1980). The current average annual use is estimated to be approximately 11,000 gpd based on an assumed use of 70 gpd per capita (E. A. Hickok and Associates, 1982).

13. Argusville

Argusville, North Dakota, is a community of approximately 147 people 8 miles northwest of Fargo on Interstate Trunk Highway 29. In 1981, Argusville began to receive its total water supply from the CRWUA. The maximum CRWUA allotment is 20,000 gallons per day. Because the old system still is functional, a 1,200-gallon pressure tank and a 25,000-gallon storage tank are used. The old 95-gpm municipal well is also still available. The 43 metered service connections are billed based on a declining block rate form with a minimum demand charge.

Argusville's wastewater is treated by a two-cell wastewater stabilization pond system built in 1970. The total storage capacity is 7.5 acre-feet (2.44 million gallons). Present wastewater flow is estimated to be 10,000 gallons per day, based on a contribution rate of 70 gallons per capita per day.

Argusville's average annual daily water use was approximately 10,000 gallons per day in 1980 (E. A. Hickok and Associates, 1982), and maximum daily municipal use is estimated to be 200 percent of average use.

14. Prairie Rose

Prairie Rose, North Dakota, is an incorporated community of approximately 76 people 2 miles south of Fargo along Interstate Trunk Highway 29. The 21 homes obtain their water from individual wells in an unnamed aquifer. Individual septic systems are used for wastewater disposal. Existing average

daily water use is estimated to be approximately 5,000 gallons based on an assumed daily per capita consumption of 70 gallons (E. A. Hickok and Associates, 1982).

Maximum daily demands are estimated to be 200 percent of the average daily use, or 10,000 gallons per day.

15. North River

North River, North Dakota, is a community of approximately 65 people located on the Red River 2 miles north of Fargo. The residents receive treated water from the CRWUA on an individual basis, and individual septic systems are used for wastewater disposal. Existing average daily water use is estimated to be approximately 5,000 gallons, based on a per capita demand of 70 gpd (E. A. Hickok and Associates, 1982). Maximum daily use is estimated to be 200 percent of the average daily value, or 10,000 gallons.

16. Briarwood

Briarwood, North Dakota, is an incorporated community of approximately 57 people 2 miles south of Fargo on the Red River. Treated water is supplied to the community in bulk by the CRWUA. The current maximum allotment is 4,900 gallons per day. Many Briarwood residents conserve their CRWUA supplies by using Red River water for lawn sprinkling. There is no elevated storage to meet emergency demands; however, the community has contracted with Horace for fire protection services. Individual septic systems are used for wastewater disposal.

Average water use in 1980 was approximately 4,400 gpd, or 76 gpd per capita (E. A. Hickok and Associates, 1982). Maximum daily use (including sprinkling, partly from the Red River) exceeds the existing CRWUA allotment.

17. Rustad

Rustad, Minnesota, is a community of approximately 44 people 7 miles south of Moorhead on U.S. Trunk Highway 75. Rustad residents obtain water from individual wells in an unnamed aquifer, and individual septic systems are used for wastewater disposal. Existing average daily water use is estimated to be approximately 4,000 gpd based on a per capita consumption rate of 80 gpd (E. A. Hickok and Associates, 1982). Maximum daily use is estimated to be 200 percent of average daily use.

18. Kragnes

Kragnes, Minnesota, is a community of 30 people 7 miles north of Moorhead on U.S. Trunk Highway 75. Kragnes residents obtain water from individual wells and use individual septic systems for wastewater disposal. Existing average annual daily water use is estimated to be approximately 3,000 gpd, based on a per capita use of 90 gpd (E. A. Hickok and Associates, 1982). Maximum daily use is estimated to be 200 percent of the average daily use.

19. Cass Rural Water Users Association

The Cass Rural Water Users Association is a non-profit organization founded in the early 1970s largely because of efforts by Mr. Willard Grager of Cass County Electric. The original intention was that the water utility and the electric utility could offer a combined service; however, circumstances led the water utility to develop its own management. Presently, the CRWUA consists of more than 1,200 miles of pipe in three separate sub-systems (termed "phases" by the utility) serving a total of approximately 7,800 people. Two of these sub-systems, or phases, serve parts of the 18 study area communities. Portions of the main transmission line within the study area are shown in Drawing 1.

The West Fargo South, or Hickson (Phase I), sub-system serves approximately 3,364 people, including the study area communities of North River, Mapleton, Briarwood, Frontier, and parts of Reile's Acres, as well as many individual farms and homeowners.

The water is supplied from three wells in the West Fargo South Aquifer about 4 miles southeast of Horace in N½ Section 3, T137N, R49W. The last well (350 gpm) was added in September 1978. Water treatment consists of disinfection plus iron and manganese removal at the main 50,000-gallon reservoir. The distribution system consists of approximately 400 miles of pipe, 925 service connections, and 260,000 gallons of storage. Initial transmission lines of 6- and 8-inch PVC were completed in January 1976. The major transmission lines within the study area are shown in Drawing 1.

Average annual production from Phase I wells since the most recent expansion has been 194,000 gpd. The maximum annual production was 223,000 gpd in 1982 (North Dakota State Water Commission, April 6, 1983).

The Page (Phase III) sub-system serves the study area community of Argusville and individual customers near the main transmission line. It reaches its easternmost limit near Argusville. Water is supplied from two wells in the Page Aquifer and treated on site. Treatment consists of iron and manganese removal and disinfection. Average annual production between 1980 and 1982 was 176,000 gpd. The maximum annual production was 213,000 gpd in 1982 (North Dakota State Water Commission, April 6, 1983).

Table 19 summarizes the water facilities data for the rural communities discussed in detail in the foregoing.

TABLE 19

WATER FACILITIES DATA - SMALL SYSTEMS

System/Community	Number of Connections (Year 1980)	STORAGE Tank Type	STORAGE Capacity (gallons)	SUPPLY Location	SUPPLY Pump Type	SUPPLY Capacity (gpm)
MUNICIPAL SYSTEMS:						
Glyndon	882	Elevated(100ft)	50,000	Buffalo Aquifer	Submersible	180
					Submersible	180
						360
Sabin	140	Elevated	75,000	Buffalo Aquifer	Submersible	250
		Pressure	1,350			
			76,350			
Riverside	173	Elevated	75,000	West Fargo Aquifer	Turbine	275
Harwood	160	(14) Pressure Tanks	14 @ 25	Undesignated Aquifer	Submersible	200
			350		Submersible	20
					Submersible	200
						420
Horace	174	Elevated	75,000	Undesignated Aquifer	Submersible	15
		Pressure	3,000		Submersible	15
		Underground	30,000		Submersible	15
			108,000		Submersible	100
						145
CASS RURAL SYSTEM:						
Mapleton	97	Elevated	50,000	-	Unavailable	150
Frontier	47	-	0	-	-	0
Argusville	43	Pressure	1,200		Turbine	95
		Ground	25,000			
			26,200			
North River	20	-	0	-	-	0
Briarwood	23	Ground	8,000		Submersible	5
Reile's Acres (See also below)	5	-	0	-	-	0

TABLE 19 (continued)

WATER FACILITIES DATA - SMALL SYSTEMS

System/Community	Number of Connections (Year 1980)	STORAGE Tank Type	STORAGE Capacity (gallons)	SUPPLY Location	SUPPLY Pump Type	SUPPLY Capacity (gpm)
INDIVIDUAL SYSTEMS:						
Reile's Acres (In addition to CRWUA)	46	-	0	-	Wells serving several small groups of homeowners	-
Prairie Rose	21	-	0	-		-
Rustad	13	-	0	-		-
Kragnes	9	-	0	-		-

NOTE:

Dashes indicate information not applicable.

In 1980, five homeowners in Reile's Acres were served individually by Cass Rural Water Users Association, the remainder by their own private systems.

D. SOCIAL, ENVIRONMENTAL, AND CULTURAL RESOURCES

1. Social Resources

Social resources of the study area include the characteristics of the people living in the area (both demographic and economic characteristics) and the governmental organizations that have been developed to meet the basic human and cultural needs. Detailed discussions of these resources appear in the urban study's Background Appendix comprising the Fargo-Moorhead Social and Environmental Inventory (Van Doren-Hazard-Stallings, 1981) and Institutional Inventory: Fargo-Moorhead (Van Doren-Hazard-Stallings, 1980). This section summarizes the existing social resources of the study area so that future social impacts related to new water developments can be identified.

a. Demographic Characteristics

The people of the study area can be described by various demographic statistics. The Census Bureau has compiled population and employment data for the Fargo-Moorhead Standard Metropolitan Statistical Area (SMSA), as well as individual data for the larger communities. The SMSA is composed of Clay County, Minnesota, and Cass County, North Dakota. The study area, however, is composed of only the 13 townships surrounding and including the cities of Fargo and Moorhead. This is a smaller area than the SMSA, but it includes most of the latter's population and employment.

The 1980 populations of the 18 study area communities are shown in Table 20. The present population of the Fargo-Moorhead urban core, including Fargo, Moorhead, West Fargo, and Dilworth, is approximately 104,000. Historically, an increasing portion of the SMSA population has been drawn into the urban communities. The percentage of SMSA residents living in the urban area has

TABLE 20

POPULATION PROJECTIONS FOR FARGO-MOORHEAD AREA COMMUNITIES

Community	Year 1980	2000	2030
Argusville	147	147	147
Briarwood	57	80	80
Fargo	61,281	71,388	99,500
Frontier	152	174	207
Harwood	540	677	944
Horace	497	601	1,000
Mapleton	307	350	700
North River	65	110	250
Prairie Rose	76	106	228
Reile's Acres	191	191	191
Riverside	465	600	600
West Fargo	10,080	15,500	23,500
Minnesota:			
Dilworth	2,578	3,180	4,358
Glyndon	882	1,007	1,084
Kragnes	30	30	30
Moorhead	29,925	38,000	45,000
Rustad	44	46	50
Sabin	630	949	1,376
Total	107,947	133,136	179,245

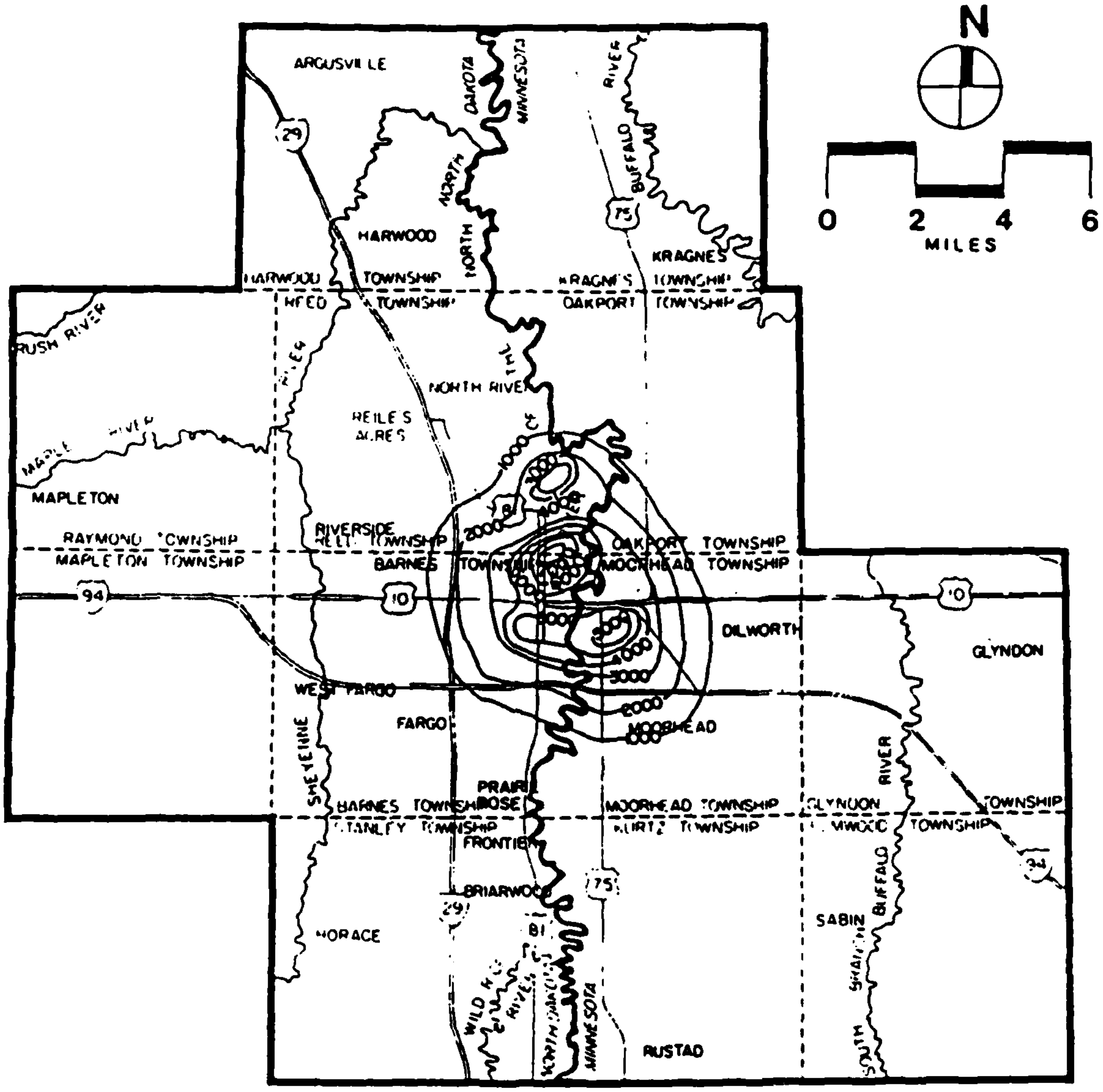
SOURCE: Phase 1, Part 1: Water Demand Projections report from the present study (E. A. Hickok and Associates, 1982).

increased from approximately 69 percent in 1960 to 76 percent in 1980. Over the last decade, rural and urban populations have grown at comparable rates, 12 and 15 percent, respectively (U.S. Bureau of the Census, various years). Much of the rural growth occurs within the rural communities as farm population continues to decline (MCOG, December 1983).

The increase in total SMSA population between 1970 and 1980 amounts to 17,336 people, or 14 percent, 4 percent more than the average growth rate of the two States. Cass County accounts for 84 percent of the total SMSA increase (Bureau of the Census, 1972 and 1983). Much of this disproportionate growth has been attributed to economic and tax advantages of living in North Dakota (U.S. Department of Housing and Urban Development, 1981).

Presently, the area's peak population densities (7,000 and 6,000 persons per square mile) occur within the cities of Fargo and Moorhead, respectively. The population density of the surrounding rural area is generally less than 1,000 persons per square mile (Van Doren-Hazard-Stallings, 1981). The geographic distribution of population density is shown in Figure 2.

Population projections for the study area communities are also shown in Table 20. The projections indicate that the Fargo-Moorhead urban core population is to remain near 96 percent of the total population for all study area communities through the year 2030. On this basis, population growth in urban and rural communities is expected to continue at a comparable rate. Between the years 1980 and 2030, the population increase of the urban core (Fargo, West Fargo, Moorhead, and Dilworth) would be 68,494 persons (66 percent). The overall percentage increase in rural community population is similar, though absolute increases in individual rural communities vary greatly, ranging from 0 to 1,780 persons per community.



SOURCE : Van Doren-Hazard-Stallings (1981).

FIGURE 2

POPULATION DENSITY
(PEOPLE PER SQ. MILE)

b. Economic Characteristics

Existing employment is dominated by the jobs offered in the Fargo-Moorhead urban core area. Employment by sector is shown in Table 21 for the communities of Fargo, Moorhead, West Fargo, and Riverside. (The available data lump Riverside with Fargo and West Fargo, and do not include Dilworth.) This urban area is a center of employment in manufacturing, trade, services, and education for the surrounding States and Canadian provinces. The economy of the study area reflects the important role of agriculture within the region.

Between 1970 and 1980, the manufacturing sector of the economy generated approximately 2,000 more jobs and grew by 70 percent. Major factors in this growth include the development of manufacturing and warehouse facilities in the Fargo and Moorhead industrial parks and fairly prosperous years in the regional agricultural picture through 1978. In 1980, agricultural-based industry employed approximately 1,700 people, or 37 percent of the urban area's entire manufacturing employment. These figures include only those industries that directly utilize raw agricultural products such as milk, meat, sugar beets, wheat, sunflowers, and soybeans. An additional 900 jobs are offered by industries closely related to agriculture, including manufacturers of agricultural equipment (figures are based on data from Fargo-Moorhead Directory of Manufacturers, Fargo Job Service, and Moorhead Job Service).

The major components of urban non-manufacturing/commercial employment are trade and service sector employment. According to local Job Service data, trade and service jobs increased faster than the overall economy during the 1970s, to compose better than 50 percent of 1979 SMSA employment (U.S. Department of HUD, 1981). Local Job Service data also show that combined urban trade and

TABLE 21

1980 EMPLOYMENT IN FARGO, MOORHEAD, WEST FARGO, AND RIVERSIDE

Sector	Number of Employees
Manufacturing	4,465
Wholesale-Retail Trade	14,987
Services	13,124
Construction	3,264
Transportation, Communication, and Utilities	2,945
Finance	3,386
Government	10,662
Total	52,833

SOURCE: 1980 Fargo and Moorhead Job Services report.

service employment was approximately 28,100. The North Dakota portion of the urban area offers 82 percent of these jobs. Consequently, many people from the surrounding study area commute to jobs in this area.

Retail trade centers within the urban area include the downtown portion of Fargo and Moorhead and the many malls that have developed along major highways. The Fargo West Acres complex, including adjacent malls, alone employs approximately 2,000 people (West Acres General Manager, March 1983).

The service sector includes jobs in motels, restaurants, health services, schools, and colleges, as well as in the many miscellaneous personal service businesses. Motels and restaurants are primarily support facilities that meet the needs of visitors who may be drawn to the area by other services or needs. In 1980, hospitals and clinics employed approximately 5,000 people and served more than 275,000 patients (Minnesota Department of Energy, Planning, and Development [1982], Fargo Downtown Business Association [1982], and MCOG [1983]).

Area technical schools and colleges include North Dakota State University, Moorhead State, Moorhead Area Vo-Tech, and Concordia College. Together, they have enrollments of more than 17,000 and employ approximately 2,000 people (Minnesota Department of Energy, Planning, and Development [1982], Fargo Downtown Business Association [1982], and MCOG [1983]). Long-term post-secondary enrollment is projected to remain constant or to decline slightly (MCOG, 1978).

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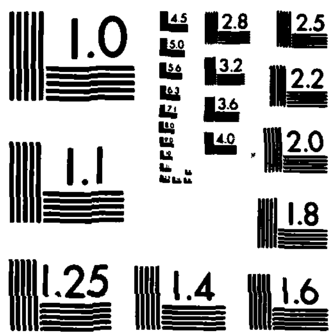

MICROCOPY RESOLUTION TEST CHART

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Construction employment peaked in 1978 and has subsequently continued to decline (Fargo Job Service). Over the last decade, the number of households (occupied housing units) has increased by 1,710 units per year (an average 4.8 percent per year) to total approximately 52,700 in 1980 (Bureau of the Census, 1983). The dollar value of building permits issued in Fargo, Moorhead, and West Fargo during the first 6 months of 1982 declined approximately 20 percent from the same period in 1981 (Moorhead Chamber of Commerce, 1983).

During 1981 and 1982, 1,060 new housing units were added per year, representing a 38-percent decline from the previously cited rate. This decline in housing starts may be attributed to inflationary pressures and the poor agricultural market (U.S. Department of Housing and Urban Development, 1981).

The agricultural farming sector of the economy employs slightly more than 5 percent of the SMSA total work force. This value tends to understate the importance of agriculture to the area's economy. It should be noted that although this sector's employment is relatively small, production can remain high since agriculture within the area is a capital-intensive (not labor-intensive) operation. The 1970s through 1978 were fairly prosperous years within the larger agricultural region, and personal income showed gains that exceeded inflation. Since then, however, substantial declines in personal income have been noted (U.S. Department of Housing and Urban Development, 1981). The condition of the region's agricultural economy has major impacts on other sectors of the area's economy. The major portion of the area's manufacturing employment depends upon agricultural-based industry. Also, the service and trade sectors rely upon income generated within the region by the export of raw and processed agricultural products.

In summary, the Fargo-Moorhead economy depends largely upon agriculture-generated income to support its manufacturing, trade, services, and construction employment. Over the last decade, the general health of these sectors has varied, with significant growth through 1978 and subsequent decline. Bright spots in the area's present economy include a high level of college enrollment and an expanding services sector, reflecting the regional importance of the Fargo-Moorhead area.

c. Governmental Organizations

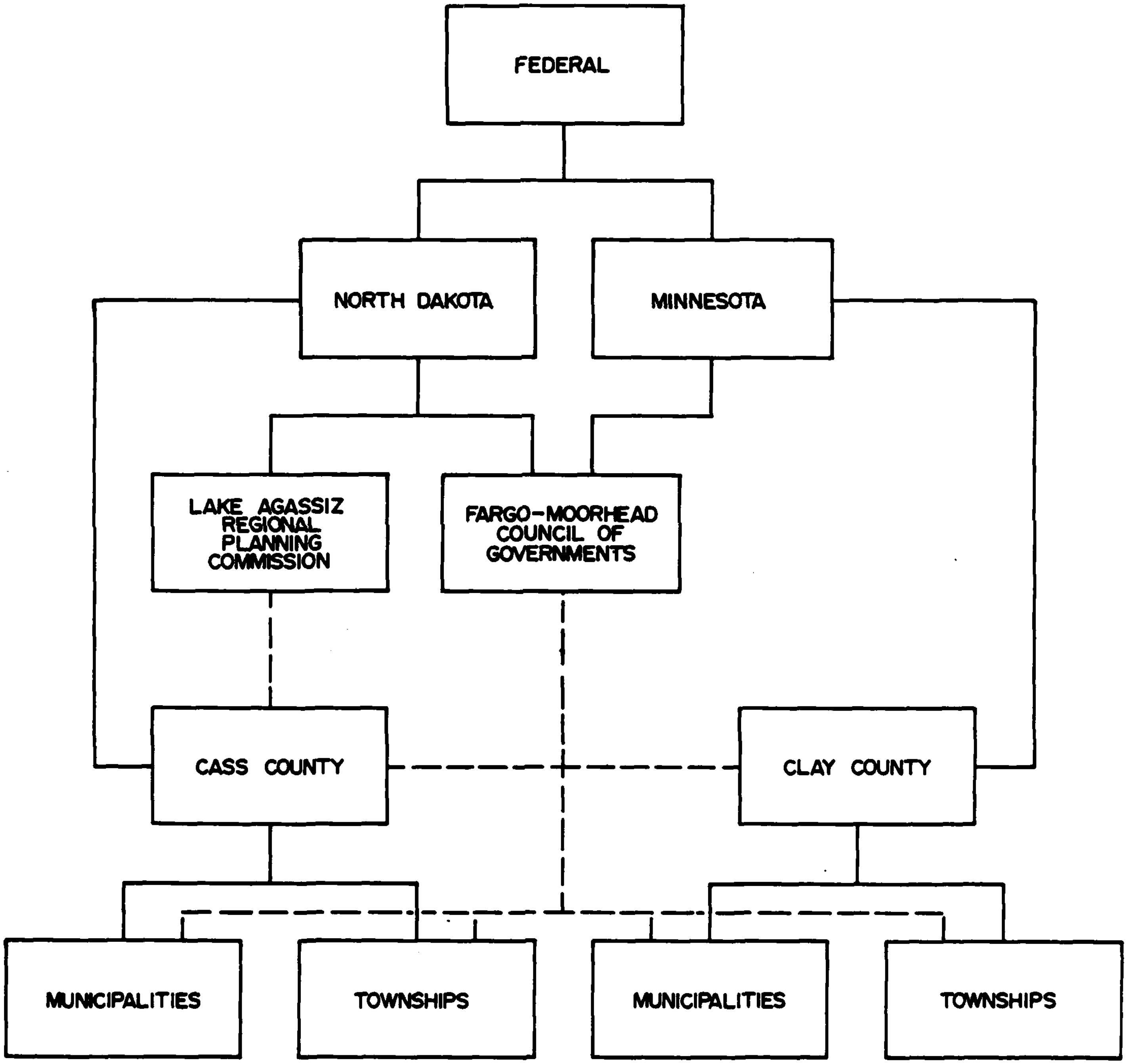
Governmental organizations influencing the study area include Federal, State, regional, county, and local institutions. The inter-relations between the different levels of government are shown in Figure 3. Detailed discussions of individual agencies are in the previously cited Institutional Inventory: Fargo-Moorhead.

At the Federal level, many agencies provide services and regulate functions specifically ascribed to them by Federal mandate. Examples include the U.S. Department of Housing and Urban Development, Environmental Protection Agency, Economic Development Administration, and Army Corps of Engineers.

Two State governments, North Dakota and Minnesota, have regulatory authority in their respective portions of the study area. Examples of State agencies with similar functions include the Minnesota Department of Transportation and North Dakota Department of Highways, the Minnesota Department of Natural Resources and North Dakota Natural Resources Council. Most of the agencies in one State have a counterpart in the other State.

FIGURE 3

LEVELS OF GOVERNMENT INFLUENCING STUDY AREA



The authorities of various regional agencies affect part or all of the study area. These agencies serve many purposes and have been established to meet specific needs in their respective regions. Regional agencies which serve parts or all of the study area include the Fargo-Moorhead Metropolitan Council of Governments and the Lake Agassiz Regional Planning Commission. These agencies coordinate regional planning and aid local governments in their development efforts.

Cass County, North Dakota, and Clay County, Minnesota, provide public services and capital improvements within their respective jurisdictions. Highway construction, health and welfare, land use planning and zoning, and water and sewer services outside city limits are examples of county functions. Other local governmental organizations include townships, incorporated cities, and special districts organized to perform specific functions. The special districts include school, water, and watershed districts.

2. Environmental Resources

a. Water Resources and Fishery Values

The environmental resources of the area are primarily focused on water resources. These resources include both rivers and wetlands, though the latter have significantly decreased in extent due to widespread wetland drainage. The rivers of the area include the Red River of the North, Sheyenne, Wild Rice (North Dakota), Maple, Rush, Buffalo, and South Branch Buffalo Rivers.

The Red River of the North is the most significant surface water resource in the study area. The North Dakota Game and Fish Department (NDGFD) classifies the river as a Class I stream, which is considered to have the highest fishery value. The Minnesota Department of Natural Resources (MDNR) classifies the river as a warm water game fish (Class II) stream.

The ratings are justified by the Red River's good sport fishery of walleye, northern pike, sauger, crappie, yellow perch, and channel catfish. Other game fish in the river include the largemouth and smallmouth bass, pumpkinseed, white bass, rock bass, bluegill, and other sunfish.

In the lower reaches of most Red River tributaries, the predominant sport fishes are the walleye, northern pike, and channel catfish.

The NDGFD has designated the Sheyenne River as Class I from the Baldhill Dam to the Red River. A variety of habitat and substrate is present in this reach. In a study conducted by the University of North Dakota, 49 species of fish were listed as being in the river below the dam. Fish in the lower Sheyenne River are supported by natural reproduction, downstream movement of fish from Lake Ashtabula, and recruitment from the Red River. The Sheyenne River provides forage fish, reproduction sites, and nursery areas for species which normally spend their adult lives in the Red River. Many spring-fed streams in the Sheyenne River delta provide refuge for fish species requiring clean water conditions such as the blacknose shiner. Stocking of hatchery-raised walleye, northern pike, smallmouth and largemouth bass, bluegill, and channel catfish supplements the Sheyenne River's natural fish populations.

The reach of the Wild Rice River flowing through the study area is a Class II stream (NDGFD); i.e., a habitat that is intensively used by species of high interest to North Dakota. Northern pike and channel catfish support a moderate sport fishery in the river.

The habitat of the Maple River, a Class III stream, is used occasionally by species of high interest. Used occasionally implies that reduction of the habitat would not seriously impair the population of a species of high interest.

The river supports a moderately-valued sport fishery of northern pike, channel catfish, bullheads, and freshwater drum.

The Rush River was channelized during the mid-1950s for flood control. Channelization and agricultural runoff have greatly degraded the water quality. The river does not support a sport fishery and yields limited forage fish production. A few bullheads and carp utilize pool areas formed by low-water dams during no-flow periods.

The MDNR classifies the Buffalo and South Branch Buffalo Rivers as rough fish, forage fish streams, or Class IV. Twenty-eight species of fish are found in the Buffalo River. Redhorse, white suckers, and bullheads are the most abundant and commonly sought species with an occasional walleye and northern taken.

b. Wildlife Resources

Wildlife resources and their associated habitats have been greatly altered and reduced in the Fargo-Moorhead study area in the last 150 years. Most of the woodlands and wetlands and virtually all of the original grasslands have been converted to other land uses.

Native woodland remaining in the study area is confined primarily to the floodplain adjacent to and along the Red River and its major tributaries. Predominant trees include the American elm, green ash, cottonwood, box elder, bur oak, basswood, and hackberry. Important shrubs are wolfberry, gooseberry, Virginia creeper, wild grape, chokecherry, and prickly ash.

Riparian cover is very important to many wildlife species because of its habitat value. Its trees and shrubs provide resting, feeding, breeding, and nesting habitat for a greater variety of wildlife than any other cover type in the study area. Many birds and mammals use the cover for migration and travel corridors.

It also is an important ecotone, or edge habitat, adjacent to grasslands, croplands, and aquatic habitats. A greater diversity of wildlife species occurs in areas with these bordering habitats.

Not all trees and shrubs in the study area are along the rivers. Many shelterbelts and field windbreaks are established in farmed areas. A variety of permanent trees and shrubs is found in the cities of Fargo and Moorhead. These wooded areas also provide habitat for birds, tree squirrels, and other wildlife in the study area.

The Sheyenne Delta sandhills are a unique area of North Dakota. The extensively wooded area along the river and the savannah vegetation of the sandhills contain rare species of vegetation and provide habitat for rare species of animals. This community is in part due to the high water table in the area. The area provides many recreational opportunities, including hunting, fishing, camping, sightseeing, and canoeing.

Drainage has eliminated the vast majority of wetland habitat within the Fargo-Moorhead area. The natural wetland basins that still remain provide breeding, nesting, feeding, and resting areas for waterfowl and other water birds. Big game, small game, furbearers, and other wildlife also benefit from these few remaining wetlands for breeding and the rearing of their young.

Wetlands are not only important to wildlife; indeed, they provide substantial benefits to mankind. They retain water during high runoff periods, and thus are a natural means of flood control. In the Devils Lake basin, North Dakota, wetlands can retain 72 percent of a 2-year runoff and 41 percent of a 100-year runoff. Wetlands also serve as ground-water recharge areas, nutrient and

erosion traps, and chemical sinks and, thereby, exert a positive effect on water quality. They can be more efficient in removing some pollutants, such as phosphates and nitrates, than are most wastewater treatment facilities.

Native grassland, once a vast cover, now exists in very few parts of the study area; e.g., old cemeteries, country school yards, railroad rights-of-way and similar undisturbed areas. Representative species include big and little bluestem, switchgrass, Indiangrass, prairie cordgrass and prairie dropseed. When found in combination with wetland complexes, native grassland forms an ecosystem that supports a diversity and abundance of birds, mammals, invertebrates and plants.

Tame pasture/hayland is dominated by perennial grasses and forbs and is mowed or grazed. Domestic grass species tend to include crested wheatgrass, bromegrass and alfalfa. The cover type is associated with road, highway and other public rights-of-way. Some of it is randomly located in pastures and other publicly-owned lands. Although overgrazed and early mowed, the cover does provide a broad habitat base for wildlife. They include mammals, rodents, ground-dwelling and ground-nesting birds, and some of the large predators in the study area.

Cropland predominates land use in the study area. The low diversity of these annual plantings seriously limits the diversity of wildlife habitat and species that could normally occur. Cultivation methods and high chemical use also reduce the number of plant and animal species and habitat diversity. Intensive cropland practices have essentially created an artificial environment.

Urban land in the study area includes areas of high human population concentrations, heavy traffic corridors, business lanes, housing tracts, landscaped lawns, and sidewalks. Some typical urban plants are the American and

Siberian elm, ash, junipers, and Kentucky bluegrass. Urban wildlife species include Brewer's blackbird, starling, chipping sparrow, robin, chimney swift, rock dove, tree squirrels, cottontail rabbits, and an occasional skunk and raccoon.

Over 250 species of birds have been observed in the study area. Many are important species found only seasonally or for short periods. The more common breeding birds in woodlands located along rivers in the Red River Valley floodplain include the following: red-tailed hawk, Cooper's hawk, great horned owl, bluejay, yellow-shafted flicker, black-billed cuckoo, red-eyed vireo, mourning dove, screech owl, eastern bluebird, common grackle, mallard duck, wood duck, and ring-necked pheasant. Passerine birds extensively use the woodland areas as migration corridors during the spring and fall.

Numerous waterfowl pass through the study area during spring and fall migration periods. Other water birds common to the rivers and wetlands in the study area include such species as the belted kingfisher, spotted sandpiper, marsh hawk, and marsh wren.

A total of 48 mammalian species of special interest have been identified in the study area. The white-tailed deer is the primary big game animal. Its population density in the study area is low, with about 0.3 deer per square mile. Some of the more common small mammals and furbearers are the cottontail rabbit, tree squirrel (grey, fox, and red), jackrabbit, raccoon, and red fox. The cottontail rabbit and tree squirrel are the predominant small game mammals in the urban areas. The deer, red fox, and raccoon are usually found in the more wooded and undeveloped riverine corridors.

c. Threatened and Endangered Species

Two federally-listed threatened or endangered species may occasionally be found within the study area -- the bald eagle and peregrine falcon. The bald eagle is listed as an endangered species in North Dakota and as a threatened species in Minnesota. The peregrine falcon is classified as an endangered species in both States. Both species would be present only in a migratory or transient status. There are no records of these birds nesting or having permanent residence in the study area.

There are 44 other species of birds, mammals, plants, fish, mussels, reptiles, and amphibians found in the study area that are of State significance. These species are rare, unique, peripheral, or of other value; they include the osprey, prairie chicken, ground cedar, lake sturgeon, and tree frog. These species are listed in the previously cited Fargo-Moorhead Social and Environmental Inventory.

The U.S. Fish and Wildlife Service's (FWS) Mitigation Policy (Federal Register; January 23, 1981) is used by the FWS in the evaluation of impacts to land and water resources and in the subsequent recommendations to mitigate adverse impacts. The policy establishes four resource categories, designation criteria, and mitigation planning goals for cover types affected by a project:

Resource Category	Designation Criteria	Mitigation Planning Goal
1	High value for evaluation* species and unique and irreplaceable on a national basis or an ecoregion basis.	No loss of existing habitat value. FWS will recommend that losses be prevented.
2	High value for evaluation species and scarce or becoming scarce on a national basis or an ecoregion section.	No net loss of in-kind and habitat value. Losses are to be compensated by replacement of the same kind of habitat.

*Fish and wildlife species that are representative of the cover types occurring in a project area and that reflect the projected habitat changes, both positive and negative, that would result from project development.

Resource Category	Designation Criteria	Mitigation Planning Goal
3	High to medium value for evaluation species and relatively abundant on a national basis.	No net loss of habitat value while minimizing loss of in-kind habitat value.
4	Medium to low value for evaluation species.	Minimize loss of habitat value.

Using the designation criteria, cover types in the study area fall into the following resource categories:

Cover Types	Resource Categories 1	2	3	4
Red River of the North		x		
Sheyenne River		x		
Riparian		x		
Wetlands		x		
Native Woodland		x		
Native Grassland		x		
Shelterbelts			x	
Wild Rice River			x	
Buffalo and South Branch Buffalo Rivers			x	
Maple River				x
Rush River				x
Cropland				x
Tame/Pasture Hayland				x
Urban and Built-up Land				x

The resource category determinations listed above are subject to revision. As project plans and the assessment of their impacts continue, the value of some habitats may change.

3. Cultural Resources

In accordance with Section 106 of the National Historic Preservation Act of 1966, as amended, the National Register of Historic Places has been consulted. As of December 6, 1983, 18 sites within the 13 townships surrounding Fargo and Moorhead are listed on the National Register. Of these 18 sites, eight are within Fargo and seven are in Moorhead. Because neither community has been extensively surveyed for historic standing structures, there is the potential for additional National Register sites.

Currently, 64 standing structures in and around Fargo-Moorhead have been identified as either locally significant or lacking in data adequate for determining significance. The Fargo-Moorhead area also has 17 archaeological sites. No intensive archaeological surveys have been conducted in the area, and the reconnaissance level surveys that have been conducted concentrated along the Red River north of Moorhead. These surveys, c nducted by Moorhead State University, determined that archaeological sites are usually located within one-fourth mile of the Red River or a major tributary, although sites were also located elsewhere, and are frequently deeply buried. A more detailed assessment of the existing cultural resources in the project area will be undertaken as project alternatives are developed.

IV. EXISTING AND POTENTIAL WATER SUPPLY SOURCES

A. GENERAL

The urban core of the study area presently depends on both surface and ground waters as sources of water supply. The surrounding rural communities all utilize ground water exclusively. Both existing and potential water supply sources are described in this chapter.

B. SURFACE-WATER SUPPLIES

Surface-water supply sources include study area rivers, two major upstream reservoirs, and the proposed Garrison Diversion. Each of these is discussed in the following sub-sections.

1. Rivers

Five rivers in the study area have been identified as potential sources of water supply: the Red River, Sheyenne River, Buffalo River, South Branch Buffalo River, and Maple River. The low-flow characteristics of these five rivers were analyzed in Phase 1 of the present investigations. Table 22 lists mean streamflows and 7-day, 50-year low flows projected in Phase 1 for year 2030 conditions. The Phase 1, Part 2: Low-Flow Analyses report (February 1983) presents complete statistical descriptions of the low-flow characteristics in the form of low-flow frequency curves and frequency-mass curves.

The streamflow, water quality, and reliability of supply of each river are discussed below.

a. Red River

The Red River is the major drainageway in the study area, and on a long-term basis it carries several times as much water as any of the other streams. Red River mean flows (reflecting the long term) range from approximately 400 to 600 cubic feet per second (cfs) in the study area and generally increase in the downstream direction. However, the mean flow decreases

TABLE 22

SELECTED STREAMFLOW CHARACTERISTICS PROJECTED FOR YEAR 2030

Stream	Location	Streamflow (cubic feet per second) Mean Flow	7-Day, 50-Year Low Flow
Red River	Fargo	613	18.2*
Sheyenne River	West Fargo	173	4.8*
Buffalo River	Dilworth	125	0
South Branch Buffalo River	Sabin	45	0
Maple River	Mapleton	55	0

SOURCE: Phase 1, Part 2 results from present study.

*Data here reflect diversion of 25 cfs from the Sheyenne River to the Red River during extreme drought periods. However, the diversion is being replaced by a recently completed pipeline connecting the Sheyenne River directly with the Fargo water treatment plant. Realistic projections of future Red River flows are therefore lower than as shown here; but the combined streamflow available from the Sheyenne and Red Rivers is not changed by the new pipeline.

between Fargo and North River because of major withdrawals for the Fargo and Moorhead municipal supplies. While most of this water returns to the river as treated wastewater, a large portion re-enters the river downstream of North River.

Recently, the City of Fargo completed a pipeline from the Sheyenne River to the city's water treatment plant to allow withdrawal of up to 25 cfs in times of drought. Formerly, the same flow was at times diverted via an open ditch from the Sheyenne River to the Red River. The ditch entered the Red River upstream from the city's Red River water intake and thus served a purpose similar to that of the new pipeline.

Streamflow data analyzed in Phase 1 of the present study reflect operation of the open-ditch diversion rather than the new pipeline. As a result, the low-flow statistics indicate more water in the Red River than is appropriate to the changed condition. However, since ditch losses are neglected, it is unimportant for the purposes of this study whether Fargo withdraws water directly from the Sheyenne River or indirectly via an open-ditch diversion to the Red River: the total amount of streamflow available from the two rivers is the same either way. Therefore, the streamflow data will be discussed here in a manner consistent with the analysis -- that is, as if the open-ditch diversion still operated. It is neither necessary nor practical to re-analyze the streamflows at this time.

The 7-day, 50-year low flow in the Red River is projected to be 18.2 cfs at Fargo and on the order of 1 cfs at other locations upstream. The higher flow at Fargo is the result of the diversion from the Sheyenne River. (Because the diversion occurs only a very small percentage of the time, there is almost no effect on the long-term mean flow of the Red River at Fargo.) The Sheyenne River, in turn, is generally able to deliver the flow because of controlled releases from Lake Ashtabula (Baldhill Dam), upstream of the study area.

The statistical procedures used to develop 7-day, 50-year low flows led to a projected low flow at Fargo of less than 25 cfs. This finding contradicts the apparent availability from the Sheyenne River of the full 25 cfs as needed; and indeed, the Fargo low flow of 18.2 cfs could be regarded essentially as an artifact of the analytical procedure. However, in this study the statistical result has instead been accepted at face value and is considered to reflect the possibility that, under extreme drought conditions, the Sheyenne River may not in fact be able to provide the full 25 cfs.

Tables 23, 24, and 25 present water quality data for the Red River at locations upstream of the study area (at Hickson) and within the area (at Moorhead and below Fargo). The Red River is fairly turbid, averaging around 20 turbidity units, and generally contains several hundred coliform bacteria per 100 milliliters (ml). Usual methods of water treatment reduce these contaminant levels below those specified by the primary drinking water standards. (Stated approximately, the standards set limits of 1 turbidity unit and 1 coliform per 100 ml.)

Below Fargo, mercury concentrations have averaged 0.0007 milligrams per liter (mg/l) but have ranged as high as 0.008 mg/l. This maximum value exceeds the drinking water standard of 0.002 mg/l.

Apart from the above, all other parameters having primary drinking water standards, and for which data are available, exhibit levels well below the standards. Thus, except for a possible concern with mercury levels, the Red River possesses good water quality for water supply purposes. Moderately high hardness is an aesthetic concern for water supply and could imply undesirability for certain industrial purposes.

TABLE 23

STREAM WATER QUALITY SUMMARY
RED RIVER AT HICKSON, NORTH DAKOTA
1976-1982

Parameter (units)	Mean	Range	Number of Samples
HAVING PRIMARY DRINKING WATER STANDARDS:			
Turbidity (turb. unit)	22	3-70	30
Arsenic (mg/l)*	0.003	0.001-0.005	8
Barium (mg/l)*	0.10	0.04-0.20	8
Cadmium (mg/l)*	0.002	0.000-0.003	7
Chromium (mg/l)*	0.004	0.000-0.030	8
Fluoride (mg/l)*	0.20	0.10-0.60	53
Lead (mg/l)*	0.003	0.000-0.007	7
Nitrate (mg/l as N)	0.13	0.00-0.19	4
Selenium (mg/l)*	0.001	<0.001-0.001	8
Silver (mg/l)*	0.000	--	3
Endrin (mg/l)	0.0000	--	16
Lindane (mg/l)	0.0000	--	16
Methoxychlor (mg/l)	0.0000	--	1
Toxaphene (mg/l)	0.0000	--	16
2,4-D (mg/l)	0.0001	0.000-0.0002	17
2,4,5-TP Silvex (mg/l)	0.0000	0.0000-0.00001	17
OTHERS:			
Total Alkalinity (mg/l as $CaCO_3$)	230	76-645	46
Total Hardness (mg/l as $CaCO_3$)	288	170-800	53
Calcium (mg/l as $CaCO_3$)*	139	90-350	53
pH	8.2	7.4-9.4	54
Specific Conductivity (umhos/cm)	553	47-1,590	88

TABLE 23 (continued)

Parameter (units)	Mean	Range	Number of Samples
Silica (mg/l)*	11	0.10-20	53
Iron (mg/l)*	0.076	0.010-0.30	8
Magnesium (mg/l)*	36	16-110	53
Sodium (mg/l)*	18	7.6-92	53
Potassium (mg/l)*	5.9	3.1-16	53
Bicarbonate (mg/l as HCO_3)	291	150-786	30
Sulfate (mg/l as SO_4)	83	5.4-340	53
Chloride (mg/l)	9.6	1.3-44	53
Total Dissolved Solids (mg/l)	371	224-1,180	53

*Dissolved fraction.

SOURCE: U.S. Geological Survey, through STORET retrieval by Minnesota Pollution Control Agency.

TABLE 24

STREAM WATER QUALITY SUMMARY
RED RIVER AT MOORHEAD, MINNESOTA
1978-1983

Parameter (units)	Mean	Range	Number of Samples
HAVING PRIMARY DRINKING WATER STANDARDS:			
Total Coliforms (per 100 ml)	561	0-9,100	62
Turbidity (turb. units)	22	3.8-65	62
OTHERS:			
Total Alkalinity (mg/l as $CaCO_3$)	207	125-302	62
Total Hardness (mg/l as $CaCO_3$)	260	177-542	62
Calcium (mg/l as $CaCO_3$)	147	104-280	62
pH	8.2	7.75-8.65	62

SOURCE: Derived from data provided by City of Moorhead, Water Utility.

TABLE 25

STREAM WATER QUALITY SUMMARY
RED RIVER BELOW FARGO, NORTH DAKOTA
1976-1982

Parameter (units)	Mean	Range	Number of Samples
HAVING PRIMARY DRINKING WATER STANDARDS:			
Turbidity (turb. unit)	16	3-41	24
Arsenic (mg/l)*	0.004	0.002-0.008	18
Barium (mg/l)*	0.11	0.03-0.20	10
Cadmium (mg/l)*	0.002	0.000-0.003	18
Chromium (mg/l)*	0.004	0.000-0.020	18
Fluoride (mg/l)*	0.27	0.10-0.70	71
Lead (mg/l)*	0.005	0.000-0.015	17
Mercury (mg/l)*	0.0007	0.000-0.008	18
Nitrate (mg/l as N)(1)	1.0	0.03-2.5	23
Selenium (mg/l)*	0.0002	0.000-0.001	4
Silver (mg/l)*	0.000	--	1
Radium 226 (pCi/l)	0.1	0.09-0.12	4
OTHERS:			
Total Alkalinity (mg/l as $CaCO_3$)	223	62-390	57
Total Hardness (mg/l as $CaCO_3$)	275	120-510	73
Calcium (mg/l as $CaCO_3$)*	132	75-245	73
pH	8.1	7.4-8.5	73
Specific Conductivity (umhos/cm)	641	290-1,140	75

TABLE 25 (continued)

Parameter (units)	Mean	Range	Number of Samples
Silica (mg/l)*	12	0.10-22	72
Iron (mg/l)*	0.022	0.009-0.060	18
Magnesium (mg/l)*	35	11-70	73
Sodium (mg/l)*	30	6.8-110	73
Potassium (mg/l)*	7.6	4.2-20	73
Bicarbonate (mg/l as HCO_3)	275	182-471	34
Sulfate (mg/l as SO_4)	97	20-330	73
Chloride (mg/l)*	19	4.4-96	73
Total Dissolved Solids (mg/l)	401	183-769	73

*Dissolved fraction.

(1)Nitrate + Nitrite Nitrogen.

SOURCE: U.S. Geological Survey, through STORET retrieval by Minnesota Pollution Control Agency.

Predicting future water quality is extremely difficult. Increased irrigation upstream of the study area can be expected to cause some elevation of salt concentrations in streams. The Bureau of Reclamation has conducted water quality simulations in connection with the proposed Garrison Diversion, which would include new irrigation of many thousands of acres (see subsection 3 below). Water quality changes caused by modestly increased irrigation can be judged by comparison with the Bureau's projections made for the Garrison Diversion. On this basis, modestly increased irrigation can be expected to cause increases of 10 percent or less in the concentrations of total hardness, sulfate, and total dissolved solids.

Reliability of the Red River as a water supply source is presently enhanced by upstream regulation at Orwell Reservoir and, until recently, by the Sheyenne diversion and regulation at Lake Ashtabula as well. Neither reservoir was operating during the severe drought of the 1930s. The Red River exhibited zero flow for significant periods during the 1930s drought. However, the low-flow analyses conducted in Part 1 of the present study indicate that a reliable Red River flow of 18.2 could be expected under moderately severe drought conditions (50-year recurrence interval) at least through the year 2030, assuming operation of the Sheyenne diversion. In the future, water diverted from the Sheyenne River will go directly to the Fargo water treatment plant. The total available flow from the Red and Sheyenne Rivers will remain essentially the same, however, whether the diversion is by pipeline or open ditch. In fact, the pipeline will limit water losses from seepage and evaporation.

b. Sheyenne River

The Sheyenne River is the second major river in the study area. Long-term mean flows range roughly from 150 to 225 cfs from upstream to downstream, and the 7-day, 50-year low flow at West Fargo is projected as 4.8 cfs under year 2030 conditions (Table 22). The low flow figure reflects diversion from the Sheyenne River of 25 cfs during drought periods (as discussed above) from a location upstream of West Fargo. The change from open ditch to pipeline for this diversion has no effect on the flow at West Fargo.

As previously noted, flow in the Sheyenne River is regulated at Baldhill Dam, upstream of the study area. The flow statistics developed in Phase 1 of the present study and cited immediately above reflect operation of Baldhill Dam to help meet Fargo-Moorhead water demands.

The water quality of the Sheyenne River is similar to that of the Red, but certain salts and metals have higher concentrations in the Sheyenne. Total dissolved solids in the Sheyenne River (Table 26) are approximately 25 percent higher than in the Red (compare with Tables 23 and 25). Sulfate, chloride, sodium, iron, and mercury are all substantially higher in the Sheyenne River.

As with the Red River, the Sheyenne River has contaminant levels well below corresponding primary drinking water standards, except for coliform bacteria, turbidity, and mercury. The average mercury concentration in the Sheyenne River, 0.004 mg/l, is double the drinking water standard, 0.002 mg/l. Concentrations in the river have ranged as high as 0.040 mg/l, or 20 times higher than the drinking water standard.

TABLE 26

STREAM WATER QUALITY SUMMARY
SHEYENNE RIVER NEAR KINDRED, NORTH DAKOTA
1975-1983

Parameter (units)	Mean	Range	Number of Samples
HAVING PRIMARY DRINKING WATER STANDARDS:			
Total Coliforms (per 100 ml)	961	10-4,200	47
Turbidity (turb. unit)	26	1.1-130	48
Arsenic (mg/l)	0.006	0.003-0.014	32
Barium (mg/l)	0.17	<0.10-0.60	31
Cadmium (mg/l)	0.001	0.000-0.002	21
Chromium (mg/l)	0.009	0.000-0.020	32
Fluoride (mg/l)*	0.3	0.1-0.5	125
Lead (mg/l)	0.007	0.000-0.025	19
Mercury (mg/l)	0.004	0.000-0.040	32
Nitrate (mg/l as N)*	0.30	0.00-1.6	102
Selenium (mg/l)	0.001	0.000-0.001	32
Silver (mg/l)	<0.001	--	28
Endrin (mg/l)	0.00000	--	5
Lindane (mg/l)	0.00000	--	5
Toxaphene (mg/l)	0.000	--	5
2,4-D (mg/l)	0.00004	0.00001-0.00007	4
2,4,5-TP Silvex (mg/l)	0.00000	--	4
OTHERS:			
Total Alkalinity (mg/l as $CaCO_3$)	232	83-340	118
Total Hardness (mg/l as $CaCO_3$)	293	115-431	126
Calcium (mg/l as $CaCO_3$)*	182	70-275	126
pH	8.0	7.3-8.5	141
Specific Conductivity (umhos/cm)	784	180-1,210	182

TABLE 26 (continued)

Parameter (units)	Mean	Range	Number of Samples
Silica(mg/l)*	18	3.9-48	125
Iron (mg/l)*	2.5	<0.01-58.	108
Magnesium (mg/l)*	27	11-42	126
Sodium (mg/l)*	62	9.5-110	126
Potassium (mg/l)*	8.5	3.8-13	125
Bicarbonate (mg/l as HCO_3)	292	110-414	81
Sulfate (mg/l as SO_4)*	146	50-240	126
Chloride (mg/l)*	31	5.7-74	126
Total Dissolved Solids (mg/l)	512	200-771	129

*Dissolved fraction.

SOURCE: Derived from data provided by U.S. Geological Survey STORET retrieval.

A close inspection of the data record reveals that elevated mercury levels were found in only 1 year out of 7 years monitored. Six years with a small number of samples (2 to 4 each year) exhibited mercury concentrations always less than 0.001 mg/l. During October 1978 through September 1979, however, 10 samples showed an average concentration of 0.011 mg/l. The cause of such elevated mercury concentrations during this 1-year period is not known. Since mercury's drinking water standard is based on its toxic properties, elevated mercury levels are a serious public health concern. Usual water treatment processes may reduce mercury levels, though they are not aimed at doing so.

As in the Red River, future water quality in the Sheyenne River can be expected to show increases in hardness, sulfate, and total solids concentrations on the order of 10 percent or less assuming modestly increased irrigation upstream of the study area.

Streamflow regulation makes the Sheyenne River a reliable source of water. The 7-day, 50-year drought flow is 4.8 cfs at West Fargo, and this flow does not include additional water diverted from the river upstream of West Fargo during drought periods. Sheyenne River water quality poses a concern for sometime-elevated mercury levels, but is otherwise fairly good for water supply.

c. Buffalo River

The Buffalo River carries a substantial mean streamflow (125 cfs at Dilworth) but is projected to have a nil 7-day, 50-year low flow under year 2030 conditions (Table 22). Flow of the Buffalo River is presently unregulated.

The water quality of the Buffalo River (Tables 27, 28, and 29) is generally similar to that of the Red and Sheyenne Rivers. The most prominent differences are substantially lower turbidity and higher alkalinity and hardness in the Buffalo River. Single total coliform measurements based on data furnished by

TABLE 27

STREAM WATER QUALITY SUMMARY
BUFFALO RIVER NEAR DILWORTH, MINNESOTA
1975-1982

Parameter (units)	Mean	Range	Number of Samples
HAVING PRIMARY DRINKING WATER STANDARDS:			
Total Coliforms (per 100 ml)	120,000	--	1
Turbidity (turb. unit)	11	2.1-58	47
OTHERS:			
Total Alkalinity (mg/l as $CaCO_3$)	308	160-726	65
Total Hardness (mg/l as $CaCO_3$)	382	222-578	65
Calcium (mg/l as $CaCO_3$)	235	160-436	62
pH	8.2	7.5-8.6	61
Specific Conductivity (umhos/cm)	581	332-860	28

SOURCE: Derived from data provided by City of Moorhead Water Utility.

TABLE 28

STREAM WATER QUALITY SUMMARY
BUFFALO RIVER NEAR DILWORTH, MINNESOTA
1977-1982

Parameter (units)	Mean	Range	Number of Samples
HAVING PRIMARY DRINKING WATER STANDARDS:			
Total Coliforms (per 100 ml)	290,000	--	1
Turbidity (turb. unit)	8.4	1.8-47	48
OTHERS:			
Total Alkalinity (mg/l as $CaCO_3$)	303	140-422	48
Total Hardness (mg/l as $CaCO_3$)	403	232-570	48
Calcium (mg/l as $CaCO_3$)	246	150-425	48
pH	8.1	7.4-8.5	48
Specific Conductivity (umhos/cm)	594	56-900	28

SOURCE: Derived from data provided by City of Moorhead Water Utility.

TABLE 29

STREAM WATER QUALITY SUMMARY
BUFFALO RIVER NEAR DILWORTH, MINNESOTA
1977-1978

Parameter (units)	Mean	Range	Number of Samples
HAVING PRIMARY DRINKING WATER STANDARDS:			
Fluoride (mg/l)*	0.20	0.10-0.30	3
Nitrate (mg/l as N)(1)	0.40	0.01-0.87	3
OTHERS:			
Total Alkalinity (mg/l as $CaCO_3$)	219	98-330	3
Total Hardness (mg/l as $CaCO_3$)	357	120-540	3
Calcium (mg/l as $CaCO_3$)*	200	70-300	3
pH	7.7	7.0-8.1	3
Specific Conductivity (umhos/cm)(2)	576	260-980	57
Silica (mg/l)*	14	10-18	3
Iron (mg/l)	5.9	0.29-16	3
Magnesium (mg/l)*	38	11-58	3
Sodium (mg/l)*	14	4.5-20	3
Potassium (mg/l)*	5.6	4.6-6.3	3
Bicarbonate (mg/l as HCO_3)	267	120-400	3
Sulfate (mg/l as SO_4)	165	36-230	3
Chloride (mg/l)	5.9	3.0-8.4	3
Total Dissolved Solids (mg/l)	466	168-678	3

*Dissolved fraction.

(1)Nitrate + Nitrite Nitrogen.

(2)Period 1976-1978.

SOURCE: U.S. Geological Survey, through STORET retrieval by Minnesota Pollution Control Agency.

the City of Moorhead for two points on the Buffalo River near Dilworth suggest a relatively high level of bacterial contamination. No mercury data are available for the Buffalo River.

Future water quality is expected to reflect small increases in the Buffalo River's hardness, sulfate, and total solids concentrations if irrigation increases.

The reliability of the Buffalo River as a water supply source is low because of expected periods of zero flow during a moderately severe drought.

d. South Branch Buffalo River

The South Branch Buffalo River is a minor stream. As shown in Table 22, it has a projected mean flow of 45 cfs at Sabin and a 7-day, 50-year low flow of zero. In fact, zero flow is projected to occur for more than 4 months during a drought of 50-year recurrence interval.

The water quality of the South Branch Buffalo River (Table 30) is similar to that of the Buffalo River, but with even higher alkalinity and hardness. Total hardness in the South Branch Buffalo River is approximately twice as high as in the Red and Sheyenne Rivers. Future water quality can be expected to reflect small increases in dissolved solids and related parameters, as for other study area streams if irrigation increases.

The South Branch Buffalo River is not a reliable source of water supply because of the extended periods of no flow during droughts.

e. Maple River

The Maple River is a tributary to the Sheyenne River and is also a minor stream. The projected mean flow at Mapleton is 55 cfs and the 7-day, 50-year low flow is zero (Table 22). As for the South Branch Buffalo River, zero flow is

TABLE 30

STREAM WATER QUALITY SUMMARY
SOUTH BRANCH BUFFALO RIVER NEAR DILWORTH, MINNESOTA
1975-1982

Parameter (units)	Mean	Range	Number of Samples
HAVING PRIMARY DRINKING WATER STANDARDS:			
Total Coliforms (per 100 ml)	1,400	--	1
Turbidity (turb. unit)	8.0	1.4-56	46
OTHERS:			
Total Alkalinity (mg/l as $CaCO_3$)	357	134-884	64
Total Hardness (mg/l as $CaCO_3$)	550	230-1,256	64
Calcium (mg/l as $CaCO_3$)	323	110-740	60
pH	8.1	7.4-9.2	61
Specific Conductivity (umhos/cm)	792	343-1,905	28

SOURCE: Derived from data provided by City of Moorhead Water Utility.

expected for an extended period during a drought of 50-year recurrence interval. The expected period of zero flow is between 6 and 9 months for the Maple River.

The water quality of the Maple River (Table 31) is very similar to that of the Red and Sheyenne Rivers, although hardness is significantly greater in the Maple River. As for other study area rivers, small increases in dissolved solids and related parameters can be expected in the future if irrigation increases.

Because extended periods of zero flow are expected during droughts, the Maple River is not a reliable source of water supply.

2. Reservoirs

a. Orwell Reservoir

Orwell Reservoir is on the Ottertail River in southwestern Ottertail County, Minnesota, approximately 6 miles southwest of Fergus Falls, Minnesota. The reservoir uses dual-purpose storage designed to capture water during flood periods and to release this water during low-flow periods for water supply and pollution abatement. It has gross storage capacity of 14,100 acre-feet, of which 13,100 acre-feet is useful capacity. The reservoir began operating in 1953.

The normal pool elevation is kept at 1070.0 feet NGVD until the winter months, when the reservoir is drawn down to an elevation of 1048.0 for the spring thaw. This minimum elevation is normally reserved to maintain fish life. Only in case of extreme drought does this storage become available for water supply.

The area has a history of flooding, and one of the reservoir's purposes is the reduction of damages caused by flooding in the lower reaches of the

TABLE 31

STREAM WATER QUALITY SUMMARY
MAPLE RIVER WEST OF FARGO, NORTH DAKOTA
1973-1980

Parameter (units)	Mean	Range	Number of Samples
HAVING PRIMARY DRINKING WATER STANDARDS:			
Total Coliforms (per 100 ml)	179	<10-500	19
Turbidity (turb. unit)	21	3-53	6
Arsenic (mg/l)*	0.008	0.004-0.012	6
Barium (mg/l)*	0.014	0.005-0.022	2
Cadmium (mg/l)*	<0.002	--	4
Chromium (mg/l)*	<0.002	--	4
Lead (mg/l)*	0.002	0.000-0.003	3
Nitrate (mg/l as N)	1.2	0.014-5.8	16
Selenium (mg/l)*	0.002	0.002-0.002	2
OTHERS:			
Total Alkalinity (mg/l as $CaCO_3$)	230	68-344	15
Total Hardness (mg/l as $CaCO_3$)	370	105-751	40
Calcium (mg/l as $CaCO_3$)	228	70-462	21
pH	8.0	7.5-8.6	20
Specific Conductivity (umhos/cm)	820	168-1,400	16
Iron (mg/l)	0.24	0.04-0.54	5
Magnesium (mg/l)	39	9-70	21
Sodium (mg/l)	68	8.5-190	21
Potassium (mg/l)	10.0	7.0-14.3	13
Bicarbonate (mg/l as HCO_3)	274	83-421	14

TABLE 31 (continued)

Parameter (units)	Mean	Range	Number of Samples
Sulfate (mg/l as SO_4)	213	41-604	40
Chloride (mg/l)	30	0-75	40
Total Dissolved Solids (mg/l)	683	168-1,561	23

*Dissolved fraction.

SOURCE: Derived from data provided by North Dakota Department of Health STORET retrieval.

Ottertail River. Another purpose of the reservoir is to supplement natural flows at times of low flow in the Red River. Agriculture is the primary land use in the vicinity of the reservoir.

The Cities of Breckenridge and Moorhead, Minnesota, and Wahpeton and Fargo, North Dakota, often contended with shortages in water supply and problems with pollution abatement as well as flooding. This reservoir has helped reduce these problems.

Because of the nature and distribution of the reservoir lands, there is an excellent opportunity for pheasant production. In addition, the reservoir forms many ponds and temporary water areas that improve waterfowl nesting and feeding. Because of its proximity to the prairie pothole region, the reservoir is used mainly as a hunting area instead of for other recreational purposes.

b. Lake Ashtabula Reservoir

Lake Ashtabula Reservoir is on the Sheyenne River, 271 river miles above the confluence of the Sheyenne River and the Red River of the North, 16 river miles above Valley City, and approximately 75 highway miles west of Fargo, North Dakota. The reservoir was formed by the construction of Baldhill Dam, completed in the spring of 1951. It was built to store available surface runoff to supplement failing and unsatisfactory sources of water supply. The reservoir uses dual-purpose storage for both water supply (92%) and flood control (8%), with a total usable storage volume of 69,500 acre-feet. A major constraint on reservoir operation is a lack of storage for spring runoff, especially if it is accompanied by rain.

From October 1st, the discharge is increased at a rate required to reach a pool elevation of 1262.5 feet NGVD on March 1st. Following the spring thawing period, the reservoir is held at the normal pool elevation of 1266.0 feet. Ideally at this time, the flow being discharged from the reservoir will equal the inflow to the reservoir. A maximum value of 2,400 cfs is discharged during the spring runoff with a minimum value of 13 cfs maintained during the dry periods of the year.

In later summer and fall, normally insufficient flows in the Sheyenne River basin cannot meet minimum requirements for fish and wildlife propagation. Serious bacterial pollution occurs in the river from municipal effluent and feedlot runoff.

As mentioned previously, the major purposes of the Lake Ashtabula Reservoir are water supply and flood control. The Fargo area possesses the largest allocation of water supply, with 52 percent of the total. Grand Forks and Valley City are allocated 29 and 10 percent, respectively, of the total water supply. For the Sheyenne River and other study area rivers, the present study uses streamflow statistics derived from output developed by the St. Paul District of the Corps of Engineers from the Hydrologic Engineering Center HEC-3 computer program. The HEC-3 model runs incorporated rules for reservoir operation, assuming that surface water supplies were to meet all municipal water demands. Therefore, it is assumed that the resulting streamflow statistics for droughts represent the maximum flows that can be made available through operation of Lake Ashtabula and other reservoirs.

Lake Ashtabula provides significant fishing opportunities and wildlife habitat in an area where there are few natural lakes. The fishing and waterfowl hunting opportunities of the Ashtabula area are an important recreational and economic

resource to the region. The Sheyenne River flood control study (Corps of Engineers) contains additional information on the importance and use of Lake Ashtabula.

Some modifications have been undertaken since the completion of the Baldhill Dam. Repairs have been made on both slopes of the dam to stabilize areas which have been subject to erosion. Modifications were also made to control foundation seepage. There are still two major concerns regarding the dam that will require future modifications. The upstream and downstream slope embankments of the dam apparently do not meet current slope stability requirements, and the dam does not have sufficient spillway capacity to prevent these embankments from being overtopped during relatively rare floods.

In August 1981, a preliminary plan was proposed to raise the dam and the design flood pool 5 feet. The purpose of this modification is to provide additional flood control storage and meet stability requirements. The centerline of the modified dam structure will be 40 feet further downstream and both the upstream and downstream facing slopes will be flattened to meet current slope stability requirements. These modifications are part of the selected plan presented in the U. S. Army Corps of Engineers report of August 1982 for the Sheyenne River basin. This project will be implemented by the Corps of Engineers with coordination and participation of non-Federal interest groups.

3. Garrison Diversion

Garrison Diversion is a major inter-basin transfer project aimed at providing irrigation, municipal, and industrial water; fish and wildlife conservation and enhancement; recreation; flood control; and other purposes. The diversion would

transfer water from the Missouri River to the Sheyenne River and other Red River tributaries. A major element would be Lonetree Reservoir (535,000 acre-feet of total storage), to be located at the headwaters of the James River, Sheyenne River, and a tributary to the Wintering River.

The recommended plan would ultimately irrigate 250,000 acres of cropland. If implemented, irrigation return flows and other releases would significantly increase streamflows in the Sheyenne and Wild Rice (ND) Rivers, and hence in the Red River as well.

The Bureau of Reclamation has mathematically modeled the impacts of Garrison Diversion under the recommended plan (U.S. Department of the Interior, 1979). Their results indicate flow increases in the Sheyenne and Wild Rice Rivers of 50.7 and 12.1 cfs, respectively, for 10-percentile (low) flows. Based on analysis of streamflow data used in the present study, it is estimated that the 7-day, 50-year low-flow increases would be 3.7 cfs in the Sheyenne River and 0.89 cfs in the Wild Rice River.

The Bureau of Reclamation's modeling study projected a mean total dissolved solids concentration of 540 mg/l for the Sheyenne River at Lisbon, North Dakota, under the recommended plan. For comparison, the historic mean used in the Bureau's study is 508 mg/l; therefore, the projected increase is approximately 6 percent. Additional water quality projections for the Sheyenne River at Lisbon are as follows:

Parameter	Mean Concentration (mg/l) Historic	With Diversion	Percentage Increase
Total Hardness (as $CaCO_3$)	269	310	15%
Sulfate	166	200	20%
Total Dissolved Solids	508	540	6%

Similar projections for the Wild Rice River near Abercrombie, North Dakota, are as follows:

Parameter	Mean Concentration (mg/l) Historic	With Diversion	Percentage Increase
Total Hardness (as $CaCO_3$)	508	760	50%
Sulfate	425	540	27%
Total Dissolved Solids	951	1,150	21%

Because the Wild Rice River (ND) makes a relatively small contribution to the total streamflow of the Red River, the pronounced water quality impacts in the Wild Rice River imply only minor water quality changes in the Red River.

Portions of the Garrison Diversion project have been constructed, but the Canadian government and environmentalists in the United States strongly oppose completion of the project. A scaled-down current phase (85,000 acres to be irrigated) is now proposed. If implemented, the current phase is not expected to alter study area streamflows or water quality significantly. In spite of present opposition, the potential exists for full development of the recommended plan in future decades.

C. GROUND-WATER SUPPLIES

1. General

Ground-water sources are used extensively in the study area for municipal, industrial, and agricultural needs. With the exception of Fargo and Moorhead, all the remaining communities rely on ground water for their water supply.

Within the study area, six distinct aquifers exist: the Buffalo, Moorhead, Kragnes, Fargo, West Fargo, and West Fargo South Aquifers. The West Fargo South Aquifer has also been known as the Hickson Aquifer. The extent of these

aquifers and their location with respect to the study area are shown in Figure 4. A seventh, ill-defined aquifer called the Ridges Aquifer exists in the area as well. In this study, the Ridges Aquifer is classified among undifferentiated sand and gravel aquifers. The Buffalo, Kragnes, and Moorhead Aquifers in Minnesota and the Fargo and West Fargo Aquifers in North Dakota are presently used for municipal, industrial, and agricultural purposes. In addition to the aquifers referenced above, several significant aquifers outside the study area may play a significant role in providing needed water supplies in the future. These additional aquifers are the Page, Sheyenne Delta, Bantel, Tower City, and Dakota. These aquifers are shown on Figure 5. A primary source of information on the North Dakota aquifers is the series of reports, Geology and Ground Water Resources of Cass County, North Dakota (Klausing, 1966 and 1968).

Information concerning the physical and hydraulic characteristics of the aquifers ranges from extensive to minimal. Aquifers presently being used extensively, such as the Buffalo, Moorhead, Fargo, and West Fargo, have been fairly well documented. Consequently, much information is available concerning their physical and hydraulic characteristics. For the remaining aquifers, however, detailed studies have not been undertaken, and specific information, particularly concerning hydraulic characteristics, is not well defined.

An evaluation of the aquifers has been undertaken to establish current withdrawals and safe yields. The safe yield of an aquifer is the amount of water that can be withdrawn annually without causing continued decline in the ground-water levels, assuming proper well spacing and design. For example, it is estimated that the Buffalo Aquifer could safety yield 1.46 billion gallons per year (bgy) with proper development. Results of the evaluation are shown in Table 32. Safe yields of the study area aquifers total 3.05 bgy. Present withdrawals from these aquifers total approximately 1.37 bgy, indicating

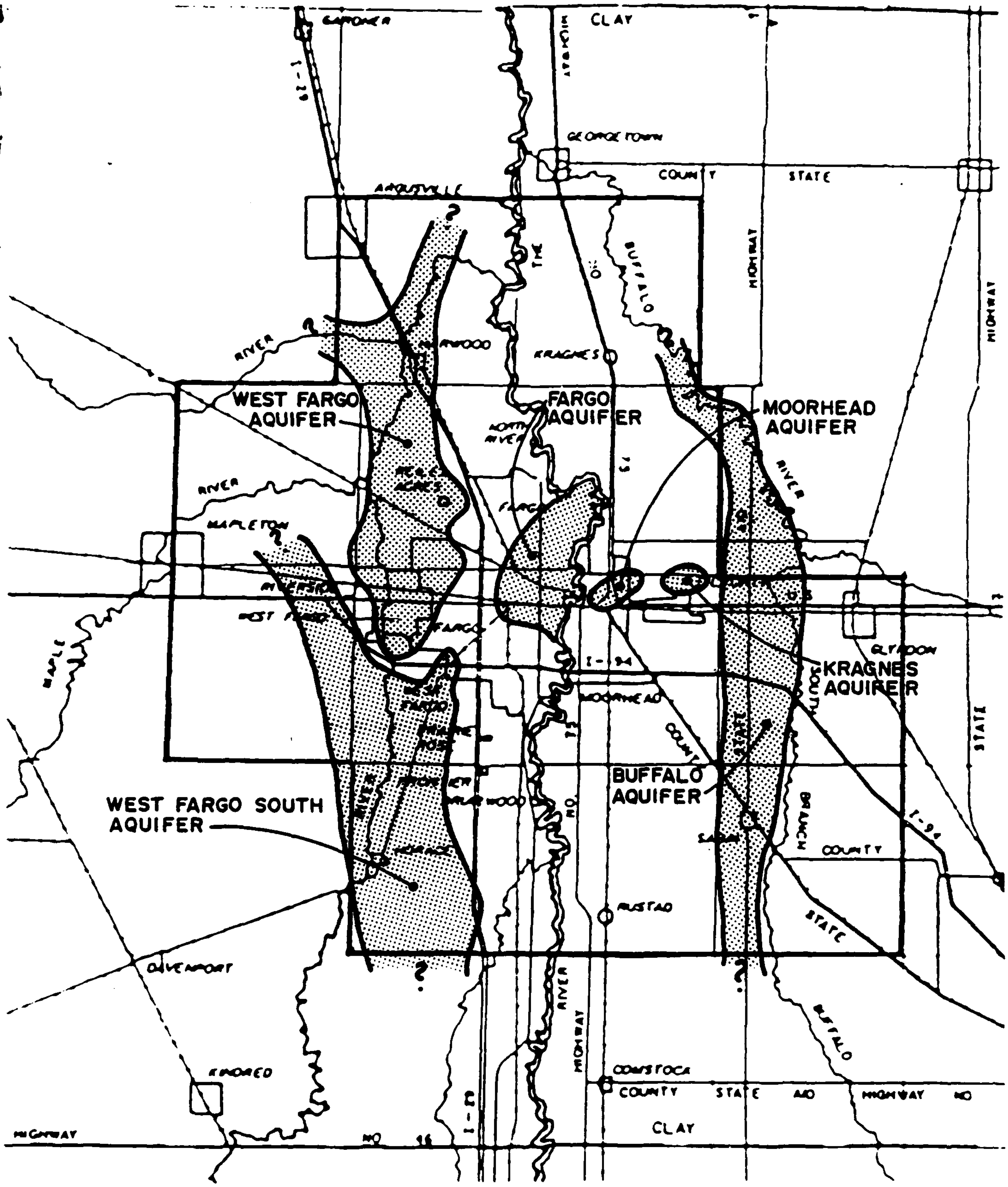


FIGURE 4
Study Area Aquifers

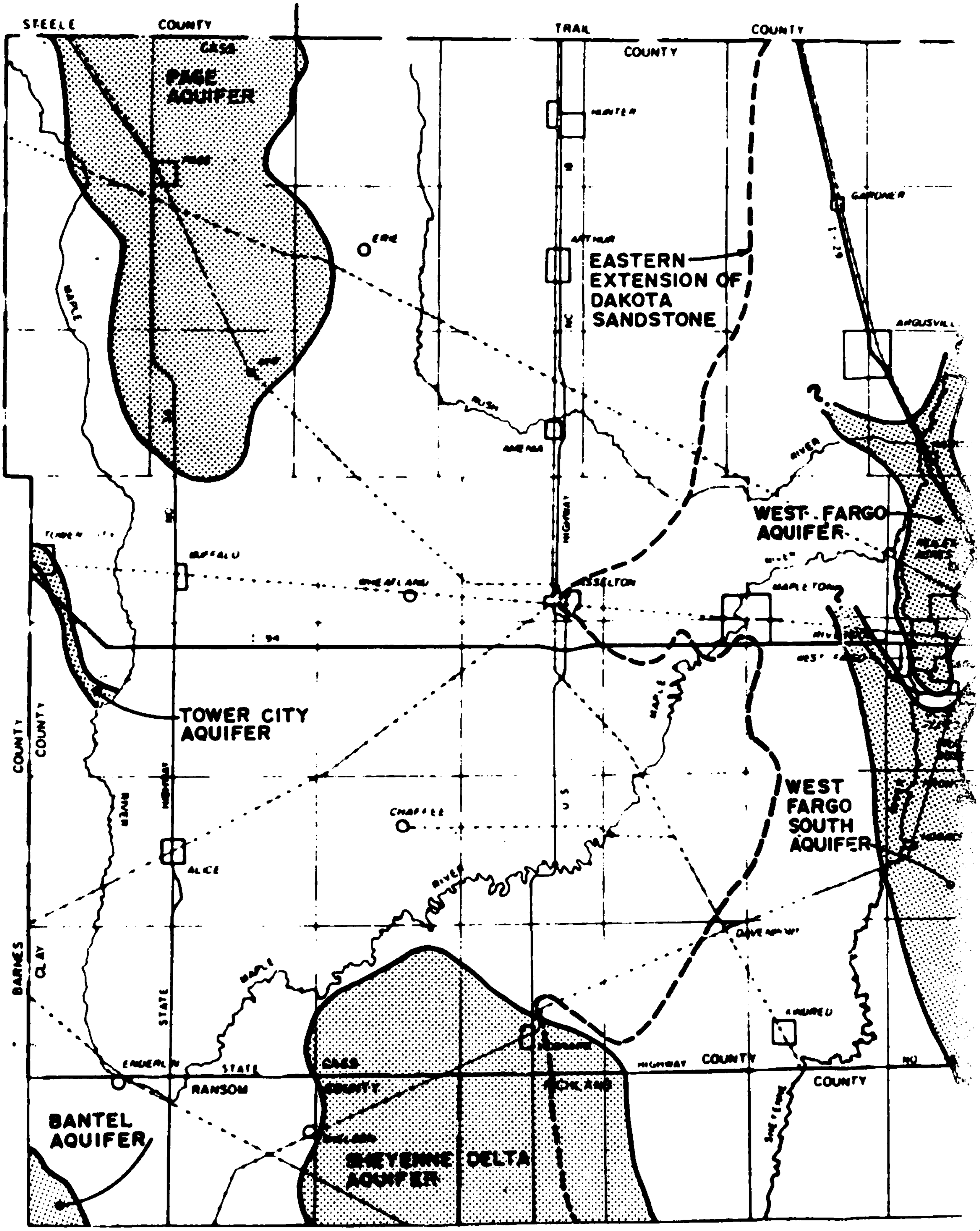


FIGURE 5
Regional Groundw ter

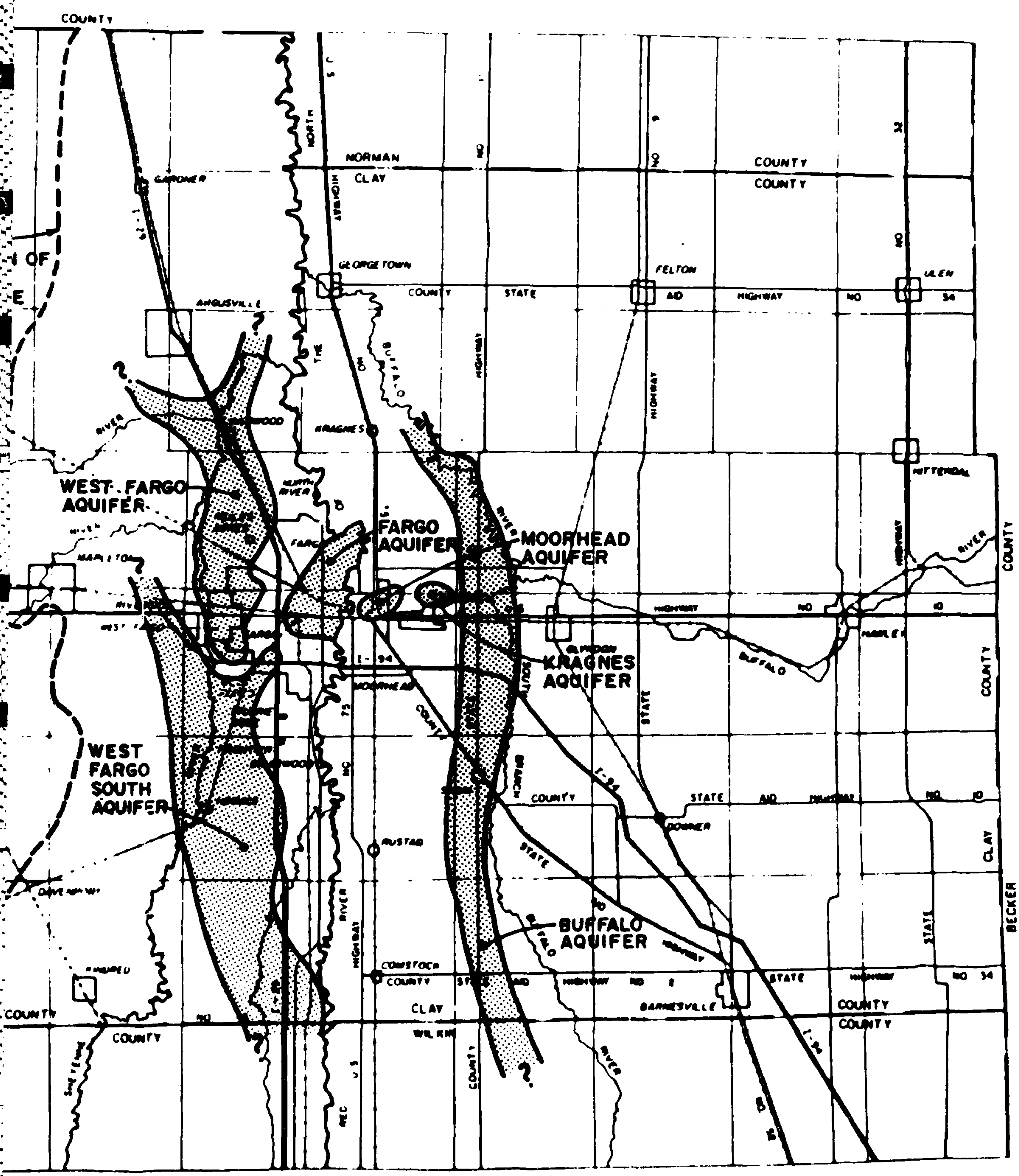


FIGURE 5
Regional Groundwater Aquifers

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TABLE 32

GROUND-WATER AQUIFERS

Aquifer	Estimated Safe Yield (bgy)	Current Withdrawals (bgy)
WITHIN STUDY AREA:		
Buffalo	1.46	0.48
Fargo	0.18	0.07
West Fargo	0.44	0.55
West Fargo South (Hickson)	0.44	0.07
Moorhead	0.44	0.12
Kragnes	0.09	0.08
TOTAL STUDY AREA	3.05	1.37
OTHER AQUIFERS:		
Sheyenne Delta	39.	0.9
Page	3.1	1.1
Bantel	--	--
Tower City	--	0.003
Undifferentiated sand and gravel	--	--
Dakota	--	0.6
TOTAL OTHER	42.+	2.6+

NOTE: Data derive from many sources, as discussed throughout text.

that an additional 1.68 bgy are available. However, present withdrawals at some locations are causing localized declines in ground-water levels on a long-term basis.

2. Buffalo Aquifer

Information sources for the Buffalo Aquifer include reports by Wolf (1981), Maclay and others (1972), and Barr (1975).

a. Location and Extent

The Buffalo Aquifer is an elongated sand and gravel body from 1 to 8 miles wide and about 32 miles long. It ranges in thickness from only a few feet at the outer edges to about 200 feet locally along the axis.

The aquifer material ranges in size from fine sand to gravel. The coarser material, mostly medium to coarse sand with gravel, is in the lower part of the narrow trough that runs north and south and that generally follows the Buffalo River.

Lake clay and silt beds overlying the aquifer vary from 80 to 120 feet thick near the outer edges to 20 feet or less in the middle of the aquifer. The overlying clay and silt beds are absent over a large area within Wilkin County and the sand is exposed at land surface.

Hydraulic characteristics have been determined from aquifer tests and test hole logs. Transmissivity of the aquifer ranges from 19,000 to 370,000 gpd per foot. Wells yielding up to 2,000 gpm have been developed, but these yields cannot generally be sustained for periods of several months or longer.

It has been estimated that the aquifer contains about 270 billion gallons of water in storage; however, only about 120 billion gallons could be withdrawn.

Recharge to the aquifer is largely in Wilkin County where the aquifer is unconfined. Elsewhere, the aquifer is locally recharged by leakage through the confining layer of lake sediments and the clay till. The direction of ground-water movement is northward. Discharge from the aquifer is to the Buffalo River and South Branch Buffalo River.

b. Safe Yield

Determination of safe yield is not an exact science; however, an estimate has been made based on recharge rate. The estimate assumes that only the unconfined area of the aquifer contributes significant recharge. Information taken from recent studies by the U.S. Geological Survey (1981) has been applied as follows:

Area of Unconfined Aquifer	21.7 square miles
Recharge Rate	4.1 inches/year

Safe Yield = 21.7 x 640 x 4.1/12 = 4,745 acre-feet/year

or 1.55 bgy

For the purposes of this study, the safe yield of the Buffalo Aquifer is assumed to be 1.46 bgy, equivalent to a long-term average of 4.00 mgd.

c. Water Quality

Water from the Buffalo Aquifer is mostly a very hard calcium bicarbonate-type that contains dissolved solids generally in the range of 300 to 1,900 mg/l.

Chemical suitability of water for municipal use and irrigation depends on the type, concentration, and relative proportions of dissolved-mineral constituents. Salinity and sodium-adsorption ratio are two factors that could be critical to plant growth and to changes in soil structure. Water from the Buffalo

Aquifer has a low sodium hazard and a medium-to-high salinity hazard according to a classification developed by the U.S. Salinity Laboratory staff (see Figure 6).

Boron in trace amounts is essential to the normal growth of all plants but is exceedingly toxic at concentrations above recommended limits. Concentrations of boron in water samples, as shown in Table 33, are below critical concentrations for crops raised in western Minnesota.

Table 33 shows a comparison for the mean, median, and range of various constituents or properties of water taken from 46 wells in the Buffalo Aquifer in 1957 and 20 wells in 1978. Although the samples were not from the same wells, the results suggest that changes may have taken place in the water quality. The table indicates higher levels of iron, calcium, magnesium, sulfate, dissolved solids, hardness, specific conductance, temperature, and color for the 1978 samples than for the 1957 samples. Conversely, the table shows lower levels of silica, sodium, potassium, sodium-adsorption ratio, sodium percentage, and pH for the 1978 samples than for the 1957 samples.

The increased concentrations of some cations and anions may reflect changes in head between the Buffalo Aquifer and the buried drift and bedrock aquifers. Such changes in head, caused by 30 years of pumping from the Buffalo Aquifer, may have induced greater upward percolation of poorer quality water from deeper aquifers, thereby altering the local chemical quality of water in the Buffalo Aquifer.

According to Maclay and others (1972), calcium bicarbonate-type water occurs in the shallow recharge areas in the eastern part of the Buffalo River watershed and progressively changes to sulfate or sodium bicarbonate-type water in the

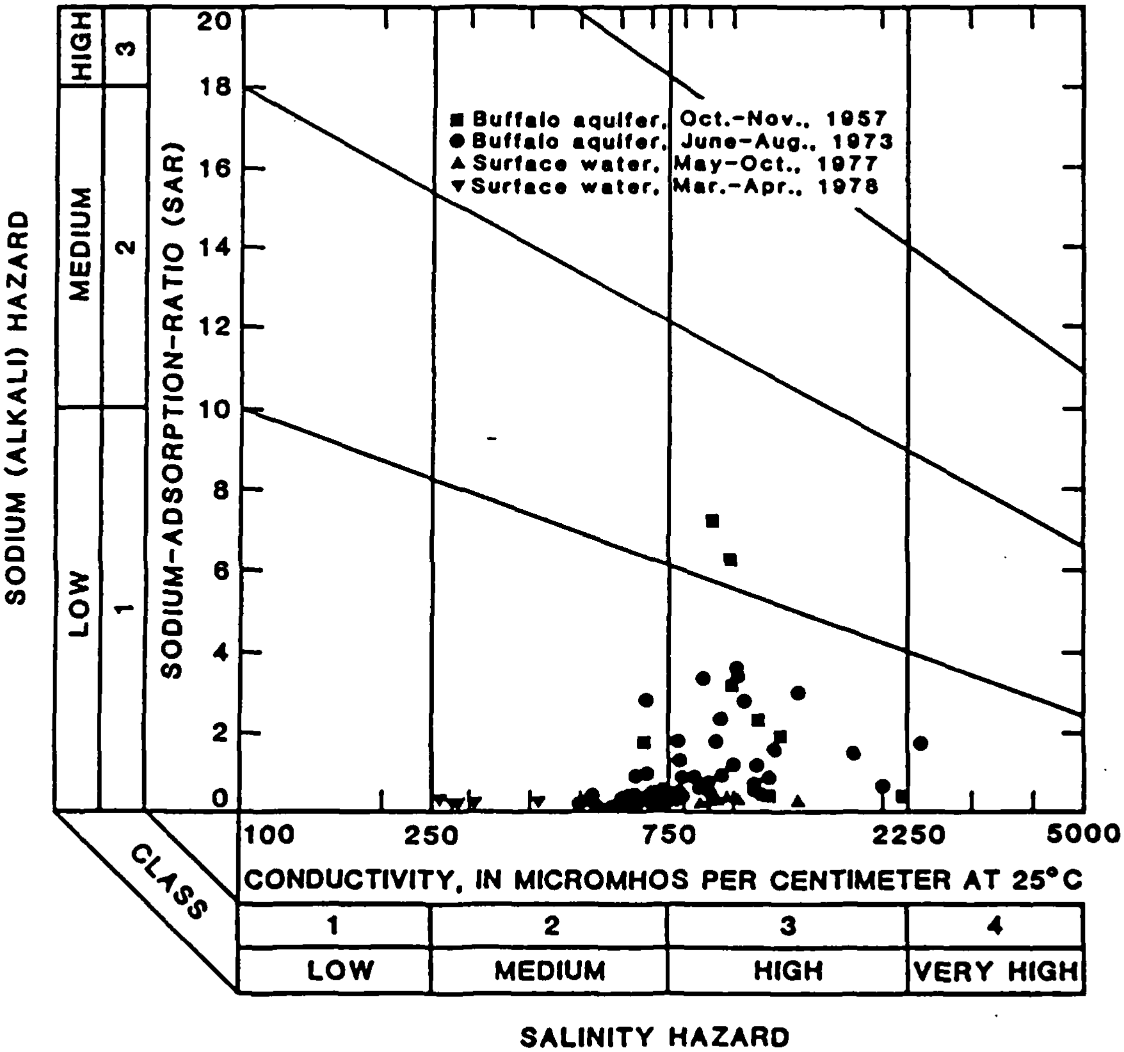

FIGURE 6
Suitability of Water from the Buffalo Aquifer
and Water from Nearby Streams for Irrigation in Terms of
Sodium Adsorption Ratio and Conductivity

TABLE 33

COMPARISON OF WATER QUALITY IN THE BUFFALO AQUIFER, 20 YEARS APART
(chemical constituents are given in milligrams per liter)

Parameter	Mean		Median		Range	
	Date Sampled Oct.-Nov. 1957	Date Sampled June-Aug. 1978	Date Sampled Oct.-Nov. 1957	Date Sampled June-Aug. 1978	Date Sampled Oct.-Nov. 1957	Date Sampled June-Aug. 1978
Silica (SiO_2)	29	26	29	25	18 - 33	21 - [illegible]
Iron (Fe), Total	1.0	11	.73	7.4	0 - 4.6	
Manganese (Mn), Total	.14	1.1	.12	.28	.02 - .35	.05 - 6[illegible]
Calcium (Ca)	88	188	84	110	32 - 181	70 - 2[illegible]
Magnesium (Mg)	34	65	33	40	13 - 83	22 - 2[illegible]
Sodium (Na)	38	33	21	10	2.9 - 159	3.2 - 14[illegible]
Potassium (K)	6.2	5	5.7	4.8	3.0 - 15	2.4 - [illegible]
Lithium (Li)	.5	--	.5	--	0 - 1.5	--
Bicarbonate (HCO_3)	362	348	358	360	279 - 478	200 - 49[illegible]
Carbonate (CO_3)	.99	0	0	0	0 - 19	
Sulfate (SO_4)	145	319	108	190	21 - 545	37 - 11[illegible]
Chloride (Cl)	7.2	7.0	3.5	4.4	0 - 39	1.1 - [illegible]
Fluoride (F)	.3	.2	.2	.2	0 - .9	.1 - [illegible]
Nitrate (NO_3)	1.0	--	.8	--	0 - 5.5	--
$NO_2 + NO_3$ Total as N	--	.53	--	0	--	0 - 1[illegible]
Nitrogen Total as N	--	.96	--	.50	--	.14 - 1[illegible]
Nitrogen Total KJD as N	--	.43	--	.39	--	.14 - .8[illegible]
Phosphate (PO_4)	.4	--	.2	--	0 - 3.3	--
Phosphorus (as P)	--	.28	--	.04	--	0 - 3.[illegible]
Boron (B)	.13	.13	.10	.09	.02 - .33	.01 - .4[illegible]
Dissolved Solids (Residue on evaporation at 180° C)	541	787	490	604	316 - 1190	305 - 189[illegible]
Dissolved Solids (Calculated sum)	512	750	488	584	305 - 1100	340 - 182[illegible]
Hardness Total	370	564	354	450	133 - 793	270 - 140[illegible]
Hardness Noncarbonate	80	273	59	140	0 - 442	36 - 100[illegible]
Sodium Absorption Ratio	1	.7	.5	.5	.1 - 3	.1 - [illegible]
Sodium Percentage	17	11	11	10	2 - 58	3 - 2[illegible]
Specific Conductivity	789	986	789	828	505 - 1500	478 - 225[illegible]
Hydrogen Ion Concentration Expressed as pH	7.8	7.5	7.8	7.5	7.3 - 8.5	7.2 - 7.[illegible]
Temperature (°C)	8.5	10.0	8.0	9.0	7.0 - 13.5	8.5 - 10.[illegible]
Color	--	--	6	5	1 - 10	5 - 3[illegible]

SOURCE: U.S. Geological Survey (1981).

direction of water flow. Calcium bicarbonate-type water extends to greater depths in the lake plain in those areas where more permeable deposits, such as the Buffalo Aquifer, form the ground-water reservoir. Sulfate-type water locally underlies bicarbonate-type water. In general, sulfate water occurs at greater distances from the recharge areas than the calcium bicarbonate water. Sulfate concentrations tend to increase from east to west, indicating a general westward movement of water.

Chloride-type water in the Cretaceous rocks and the deeper drift in the western part of the Buffalo River watershed is highly saline. Although the Cretaceous rocks contain soluble minerals that contribute to the high salinity, most of the salinity probably has accumulated during the slow northwestward migration of water. Upward discharge of the chloride-type water in the western part of the Buffalo River watershed causes mixing of chloride water with bicarbonate or sulfate water in the drift to form a calcium-magnesium-chloride type.

d. Interconnection wth Other Aquifers and Nearby Streams

Test drilling in the vicinity of the Buffalo and South Branch Buffalo Rivers indicated that the streams are generally indirectly connected to the Buffalo Aquifer. Less permeable lake sediments ranging from less than 20 feet thick locally to 100 feet thick separate the stream and aquifer.

Figure 7 shows profiles of water-level measurements in the Buffalo Aquifer and in the Buffalo and South Branch Buffalo Rivers, made at the same time as base-flow measurements in the rivers. Comparison of the potentiometric profile of the Buffalo Aquifer with the adjacent stream profile indicates that the direction of movement of groundwater, except near the Moorhead well field, is mostly from the aquifer to the stream. Before the aquifer was developed, the

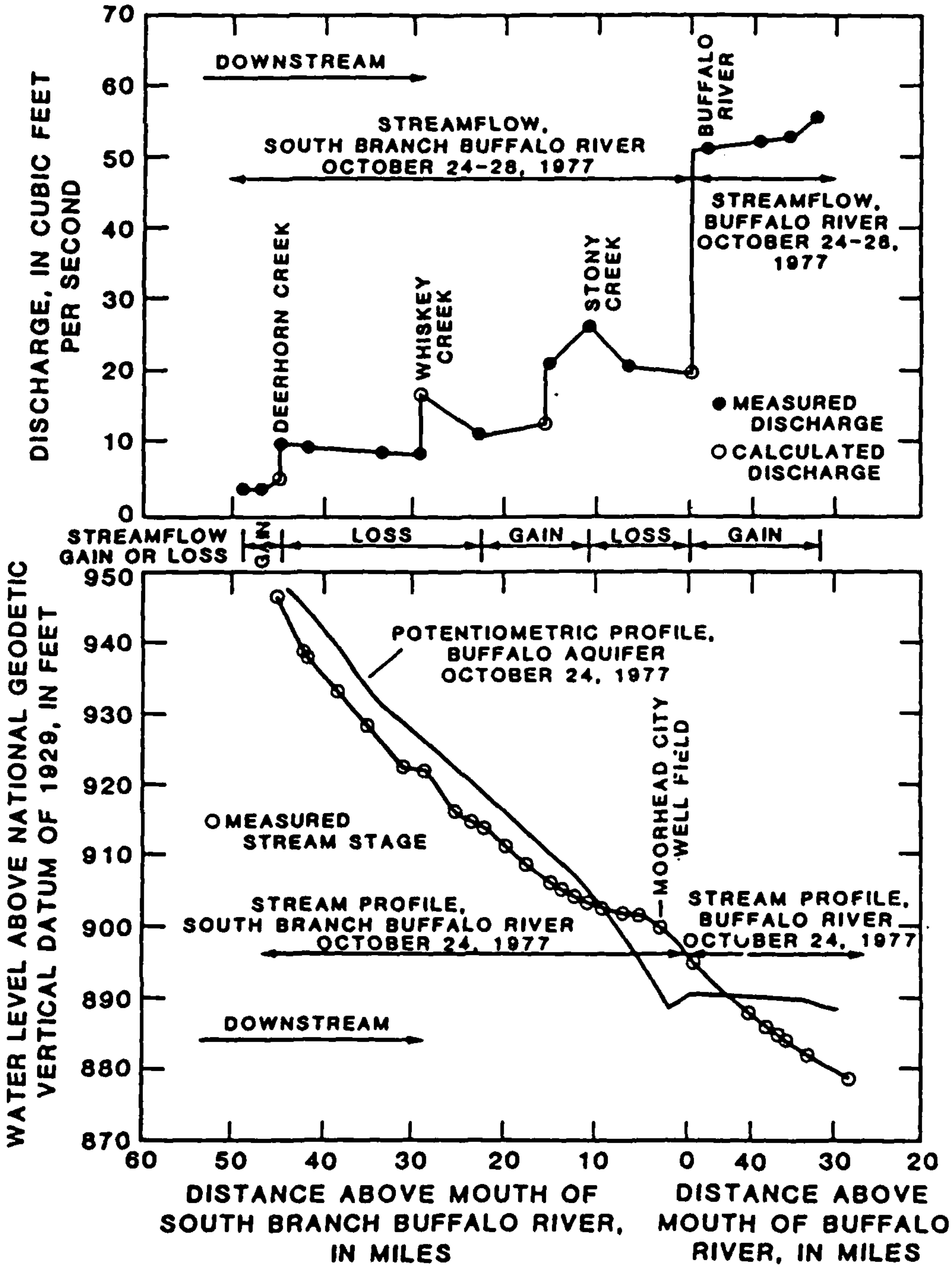

FIGURE 7

Graphs Comparing the Potentiometric Profile of the Buffalo Aquifer with Stream Profile and Flow of the Adjacent Streams at Low Flow

gradient between the aquifer and the adjacent stream was toward the stream except for brief periods during floods. In 1947, water levels in the aquifer were 9 feet above average river stage in the area where Highway 10 crosses the South Branch Buffalo River and 5.5 feet above average river stage 14 miles south of the highway (U.S. Geological Survey file data, 1947).

Base-flow measurements at or near the same time along a stream are used to evaluate the interrelations of streamflow and ground water. Base flow in a river is flow resulting essentially from ground water only. In 1976-1977, the U.S. Geological Survey made three sets of base-flow measurements along those parts of the Buffalo River and South Branch Buffalo River adjacent to the Buffalo Aquifer.

The first set of measurements was made in November 1976 when the stream was at low flow as a result of the 1976 drought. As shown in Figure 8, the measurements indicate many reaches that had no flow or that lost flow, especially along the South Branch Buffalo River and its tributaries. Some of these no flow reaches may be attributed to ice storage or storage behind beaver dams.

The second set of measurements was made in April 1977 (see again Figure 8) after the unusually small peak spring runoff for 1977. This set of measurements indicates a gaining stream except for two reaches of neither gain nor loss that generally correspond to the losing reaches along the South Branch Buffalo River shown by the October 1977 measurements.

The third set of base-flow measurements was made in October 1977 and is shown in Figure 7. This set of measurements included more closely spaced measuring sites than the earlier sets plus measurements of the main tributaries. The results

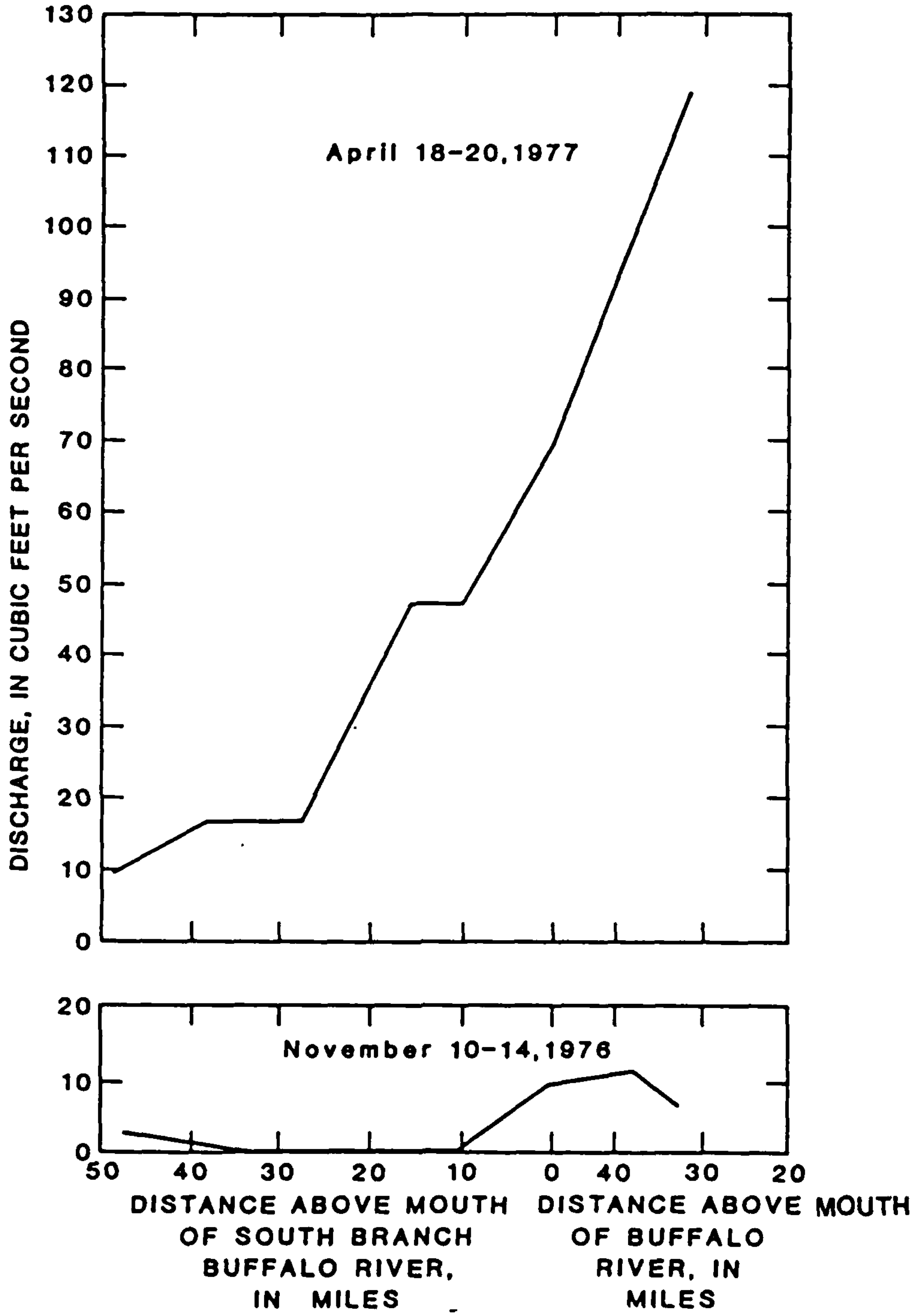

FIGURE 8

Flow of the South Branch Buffalo River and Buffalo River, April 18-20, 1977 and November 10-14, 1976

show an 11-mile losing reach along the South Branch Buffalo River downstream from Sabin which can be attributed, at least in part, to induced infiltration through the streambed and lake sediments to the Moorhead city well field. The measurements also indicate another losing reach of the South Branch Buffalo River approximately 22 miles long from Deerhorn Creek downstream past Whiskey Creek. This losing reach cannot be explained by losses to the aquifer because the head in the aquifer is higher than the stream level. More closely spaced stream-discharge measurements would probably indicate an intricate pattern of gains and losses throughout this reach. Some of the losses may be due to storage of water in wetlands and behind beaver dams or, in part, to measurement errors.

There has been speculation that the Buffalo Aquifer is interconnected with the West Fargo South Aquifer in North Dakota. The westernmost arm of the Buffalo Aquifer, in the vicinity of Comstock, Minnesota, and the eastern extension of the West Fargo South Aquifer east of Kindred, North Dakota, may suggest that these two aquifers are interconnected. Insufficient documentation is available at this time to determine whether or not such an interconnection exists, and extensive test drilling and geophysical investigations would be required in order to provide the necessary answers. This study assumes that these aquifers are not interconnected.

e. Ability to Meet Local Needs

Ground-water withdrawals from the Buffalo Aquifer are presently taken by the Cities of Moorhead, Sabin, and Glyndon. In addition, several high-capacity irrigation wells withdraw from the Buffalo Aquifer.

Table 34 presents the communities presently using groundwater from the Buffalo Aquifer, the physical characteristics of the wells, and average and maximum daily withdrawals in 1980.

TABLE 34

GROUND-WATER WITHDRAWALS - BUFFALO AQUIFER

Community	Pump Capacity (gpm)	1980 Withdrawal (mgd) Average Day	Maximum Day
Moorhead			
Well No. 8	1,150	1.16	2.88
Well No. 9	1,150		
Well No. 10	1,900		
Glyndon			
Wells	2 at 180	0.10	0.216
Sabin			
Well	250	0.06	0.13

Table 34 indicates a 1980 average daily withdrawal of 1.3 mgd for Moorhead, Glyndon, and Sabin. Irrigation demands on the aquifer, in conjunction with municipal peak demands, have caused water levels to decline in certain portions of the aquifer. This indicates that wells in such areas are too close together. It appears, however, that the aquifer as a whole is more than capable of meeting the present demands, both municipal and irrigation.

3. Fargo Aquifer

a. Location and Extent

The Fargo Aquifer is a buried glaciofluvial deposit that underlies an area of at least 10 square miles, mostly within the city limits of Fargo. As shown in Figure 9, the aquifer probably extends into Minnesota.

The aquifer ranges in thickness from 0 to about 160 feet and averages about 45 feet. The thickest part is near the south line of Section 1, T139N, R49W. The aquifer consists of fine to coarse sand interbedded and intermixed with gravel.

In the vicinity of the thickest part of the aquifer, various early investigators determined coefficients of transmissivity ranging from 1,190 to 72,000 gpd per foot (Klausing, 1968).

In 1956, a well was developed in the same area for industrial use by the Cass-Clay Creamery. During the well development test the well was pumped for 14 hours at an average pumping rate of 478 gpm and with an average drawdown of 72 feet. Because the greater part of the total drawdown in a well pumping from an artesian aquifer occurs during the first few hours of the pumping

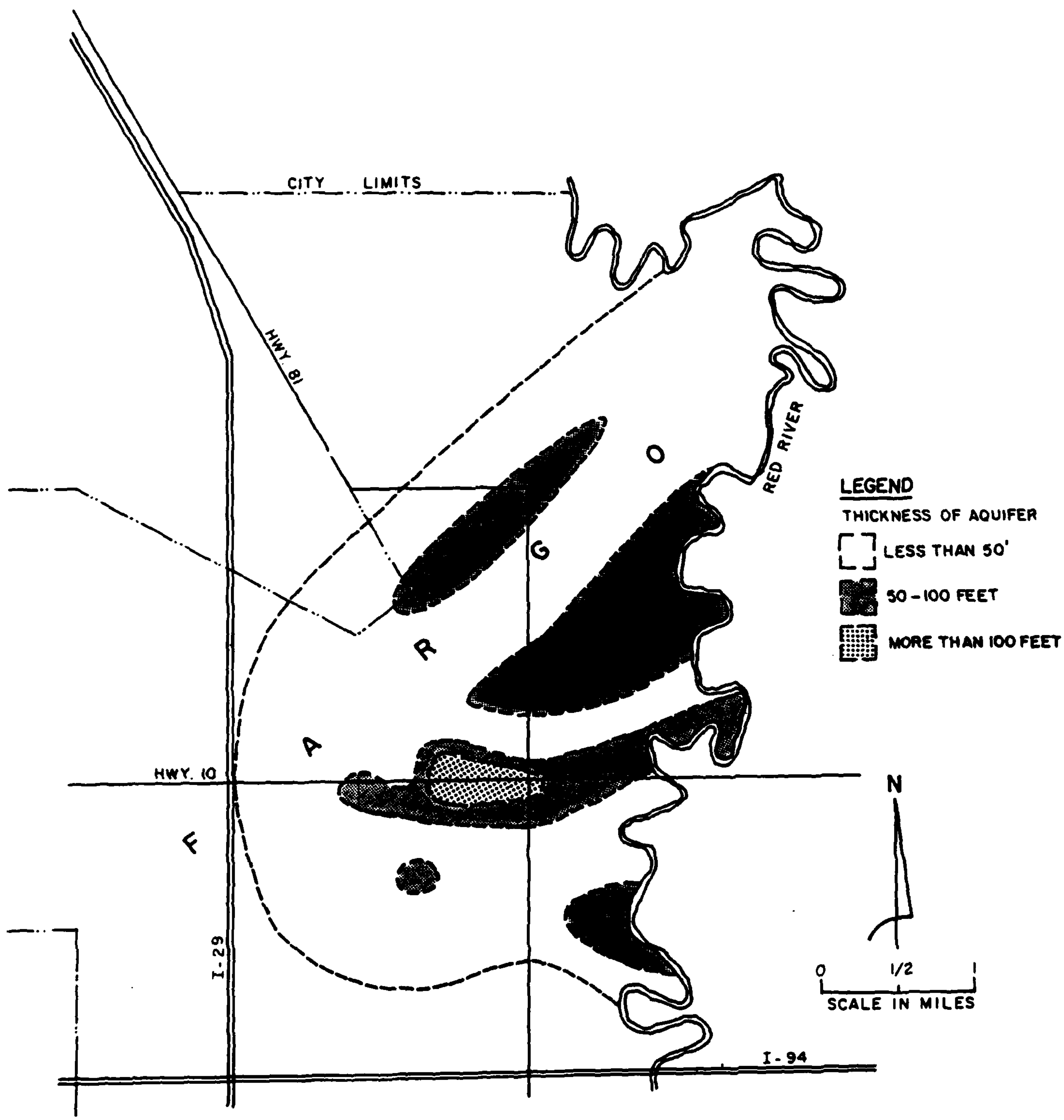

FIGURE 9
Location and Thickness of Fargo Aquifer
Source: Bulletin 47, North Dakota State Water Commission

period, the drawdown data can be used to obtain an estimate of the drawdown at the end of a 24-hour period. Assuming that pumping had continued for an additional 10 hours and that the water level in the well would not have declined more than 4 feet, the drawdown at the end of 24 hours would have been about 76 feet. The pumping rate divided by the drawdown gives a specific capacity of about 6 gpm per foot of drawdown, implying an estimated coefficient of transmissivity of about 10,000 gpd per foot (Klausing, 1968).

According to Dennis and others (1949), the storage coefficient ranges from 7.5×10^{-5} to 8.3×10^{-4} and averaged 5.8×10^{-4}. The storage coefficient represents the volume of water per unit area that the aquifer releases from storage with a unit drop in head. Thus the Fargo Aquifer releases only about 0.00058 cubic feet of water per square foot of aquifer surface area for a 1-foot drop in artesian head. Such small storage coefficients are typical of confined aquifers.

The aquifer is recharged by lateral movement of water through the till and by downward percolation of water through the overlying sediments. At the present time, water levels in the aquifer are well above the top of the till, and it seems unlikely that the aquifer receives significant amounts of recharge from the till. Recharge by downward percolation of water through the overlying materials probably will not take place until water levels in the aquifer are lowered below the base of the lake deposits. The amount of recharge reaching the aquifer by downward percolation of water probably will be insignificant because of the very low permeability of the overlying sediments and the small areal extent of the aquifer. Because water levels are 50 feet or more above the top of the aquifer, it seems likely that some water is being discharged into the adjacent deposits.

According to Dennis and others (1949), the hydraulic gradient in the Fargo aquifer in 1937 sloped to the southeast. Excluding temporary reversals, the southeasterly gradient persisted until June 1957. At that time, the hydraulic gradient underwent a long-term reversal from southeast to northwest, caused by pumping from the Cass-Clay Creamery well.

Assuming an average thickness of 45 feet and a porosity of 30 percent, it is estimated that there are 28 billion gallons of water in transient storage; however, the total yield of the aquifer would be much less (Klausing, 1968).

b. Safe Yield

From 1938 to 1952, the City of Fargo pumped water from the Fargo Aquifer to supplement supply from the Red River in summers when the river flow was inadequate or when water demands were unusually high. Withdrawals from the Fargo supply well are given below.

Year	Months	Withdrawals (millions of gallons)
1938	July, August, September, October	23.0
1939	July, August, September	18.1
1940	July, August, September	14.2
1941	June, July, August, September	54.0
1942	July, August	9.8
1943	April	2.6
1944	--	0
1945	--	0
1946	August, September	9.3
1947	July, August	13.9
1948	June, July, August, September, October	19.0
1949	August, September, October	10.7
1950	July, August	6.1
1951	May, July, August, September	8.7
1952	June, August, September	1.3

The Fargo supply well was abandoned on October 7, 1952. After that time, no significant amount of water is known to have been pumped from the aquifer until the Cass-Clay Creamery well was placed in operation June 1, 1956. The water from this well is used for cooling and washing. Prior to 1965, the volume of wastewater discharged into the Fargo sewer system indicated that the creamery well pumped about 20 million gallons annually.

In November 1960, a well was drilled in the southeast corner, Section 35, T140N, R49W for the Western Fruit Express Company. The water pumped from this well is used to wash railroad refrigerator cars. Estimated annual pumpage amounts to about 600,000 gallons.

From the above data, the amount of water withdrawn from the Fargo Aquifer between July 1938 and June 1965 is estimated to be about 372.5 million gallons (Klausing, 1968). Averaged over the whole period, this total withdrawal amounts to 0.014 bgy, or 0.038 mgd.

The water-bearing properties of the aquifer indicate that wells will yield as much as 1,000 gpm. The magnitude and extent of the drawdown cone of the Cass-Clay Creamery well demonstrate the necessity for locating new developments as far from this well as possible to avoid interference. Because of the shape and limited extent of the aquifer, it is doubtful that any new developments requiring very large quantities of water could be made without producing interference.

For the purposes of this study, the safe yield of the Fargo Aquifer is estimated at 0.18 bgy (average of 0.5 mgd) and is designated for industrial use only. No withdrawal from the Fargo Aquifer is anticipated for municipal use.

c. Water Quality

Chemical analyses of water taken from the Fargo Aquifer indicate that the water is a hard, sodium bicarbonate type. Total dissolved solids range from 750 to 1,130 mg/l, exceeding the 500 mg/l maximum recommended for drinking water by the Public Health Service. Table 35 shows a comparison of two separate chemical analyses. The analyses were taken 15 years apart and indicate no significant change in the quality of the water in the aquifer.

d. Interconnection with Other Aquifers and Nearby Streams

The Fargo Aquifer is indirectly connected to the Red River. During high river flows, water is discharged into the aquifer as evidenced by water-level fluctuations in the aquifer and in the river.

Dennis and others (1949) concluded that the Fargo and West Fargo Aquifers were interconnected. Their conclusion was based on the similarity of water level fluctuations in both aquifers. A comparison of long-term hydrographs for wells in both aquifers shows similar water-level fluctuations up to 1952. However, since 1952, similar water level fluctuations have not occurred. If there were good hydraulic connections between the aquifers, water level declines would be similar, but this is not the case today.

Although the Fargo and West Fargo Aquifers approach each other closely, there is no geological evidence to indicate that the aquifers are connected. Disregarding the lake deposits, the material lying between the aquifers consists of till, which contains thin lenses of sand and gravel. These lenses generally occur at different horizons and are considered to be not connected.

TABLE 35

GROUND-WATER QUALITY DATA
FARGO AQUIFER

Parameter	Concentration (mg/l) 1949*	1964**
Silica (SiO_2)	22	18
Iron (Fe)	0.43	0.35
Calcium (Ca)	45	49
Magnesium (Mg)	15	15
Sodium (Na) and Potassium (K)	206	206
Bicarbonate (HOC_3)	324	315
Sulfate (SO_4)	161	162
Chloride (Cl)	132	143
Fluoride (F)	0.6	0.7
Nitrate (NO_3)	3	1
Hardness as $CaCO_3$	178	185
Total Dissolved Solids	746	750

*City of Fargo well.

**Western Fruit Express Company well.

SOURCE: Klausing (1968).

e. Ability to Meet Demand

In 1980, the Cass-Clay Creamery well pumped 0.066 billion gallons, or an average of 0.18 mgd (this is substantially more than in earlier years). This is the only known major withdrawal. It appears that sufficient yield is available in the Fargo Aquifer to continue supplying the Cass-Clay Creamery unless significant increases in withdrawal occur.

4. West Fargo Aquifer

a. Location and Extent

The West Fargo Aquifer is a buried glaciofluvial deposit that extends in a north-south direction and underlies parts of Townships 137-140 N, Ranges 49-50 W (Figure 10). The aquifer ranges in width from about 2.5 miles in the southerly portion to about 8 miles in the northerly portion. Formerly, the aquifer as shown in Figure 10 was considered to comprise a single unit. However, more recent data indicate there are two distinct aquifer bodies, a north unit and a south unit. (The U.S. Geological Survey, in cooperation with the North Dakota State Water Commission, is preparing a report with recent findings on the aquifer; publication is anticipated in 1985.) For the present study, the south unit will be referred to as the West Fargo South Aquifer (sometimes formerly called th Hickson Aquifer) and will be discussed subsequently. The north unit will be termed simply the West Fargo Aquifer. To the extent available information permits, the description here of the West Fargo Aquifer will pertain in particular to the north unit.

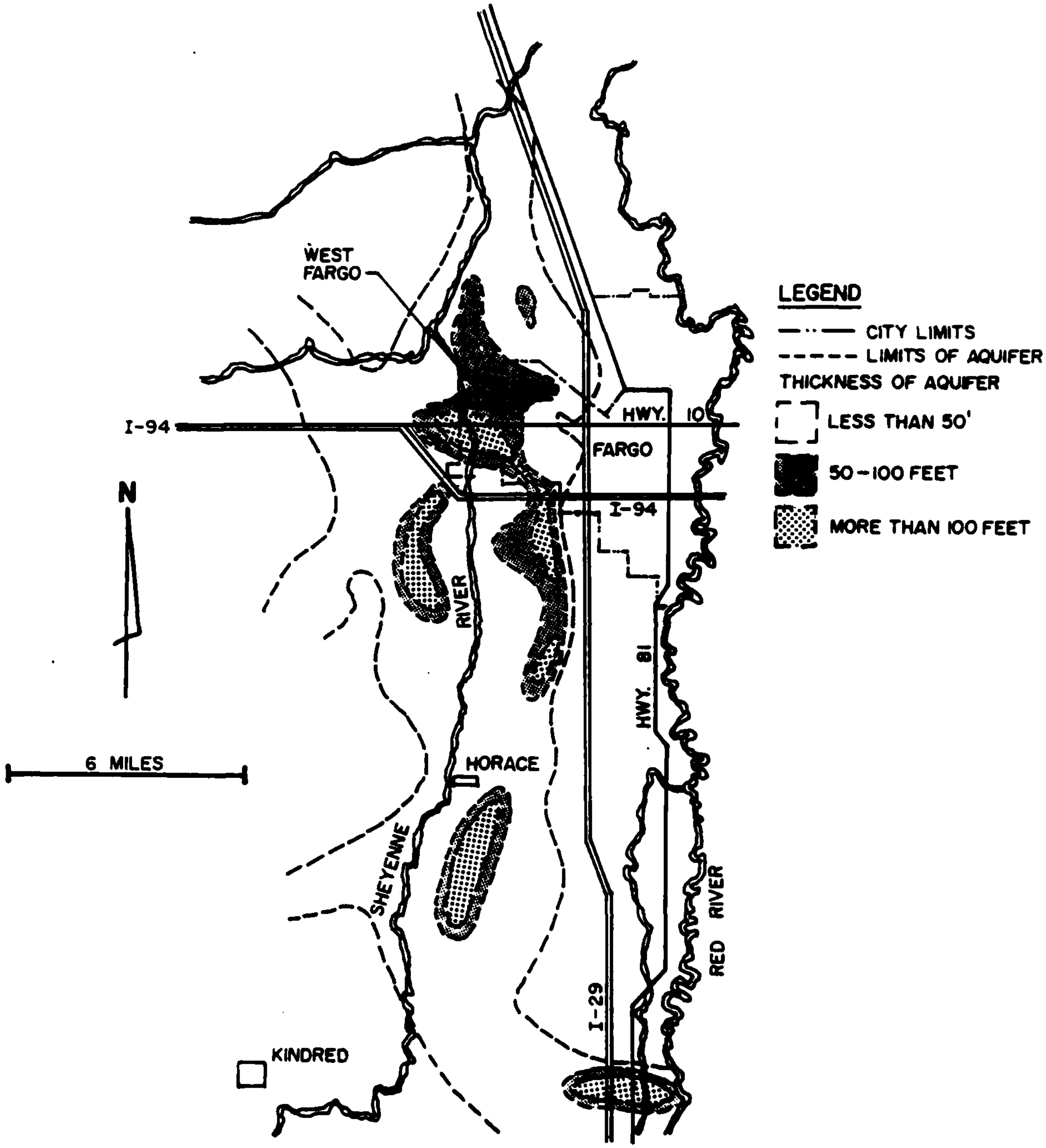

FIGURE 10

Location and Thickness of West Fargo Aquifer

NOTE: Configuration of aquifer is from Bulletin 47, North Dakota State Water Commission.

Recent unpublished data suggest a configuration as shown in Figures 4 and 5.

The West Fargo Aquifer ranges in thickness from 0 to as much as 140 feet in the northwestern part of Township 139 North, Range 49 West. The average is about 60 feet. The orientation of the thick (greater than 90 feet) aquifer segments extending southward from West Fargo suggests that these segments may be buried channel deposits (Klausing, 1968).

The aquifer is composed of material ranging in size from fine sand through boulders, and is mainly fine to coarse sand. In places, the sand and/or gravel deposits are interlensed with silt and clay. The silt and clay deposits occur most frequently near the top of the aquifer.

The West Fargo Aquifer is an artesian aquifer system that is confined at the top by deposits of glacial till and lake clay. The till, which immediately overlies the aquifer, ranges in thickness from 15 to about 90 feet. The till in turn is overlain by lake sediments consisting of plastic clay and silt that range in thickness from 60 to 90 feet. The aggregate thickness of the top confining beds ranges from 80 to about 170 feet. The basal confining units may be either granite, shale of Cretaceous age, or till. The aquifer is bounded on both sides by deposits of glacial till containing lenses and/or beds of sand and gravel that may have hydraulic connection with the aquifer.

Dennis and others (1949) report an average coefficient of transmissivity in the vicinity of the Union Stockyards well of 71,100 gpd per foot and an average storage coefficient of 3.7×10^{-3}.

In November 1963, a pumping test was run on a newly drilled municipal well in the village of West Fargo. Water levels in the pumped well and in three observation wells were measured before, during, and after the pumping period. Computations of the coefficient of transmissivity were made using the Theis nonequilibrium formula. The computed coefficients of transmissivity ranged from 74,700 to 269,000 gpd per foot and averaged 150,000 gpd per foot. The storage coefficient ranged from 2.8×10^{-4} to 5.4×10^{-5} and averaged 2.29×10^{-4} (Klausing, 1968). Table 36 presents additional physical data and aquifer test results.

b. Safe Yield

Recharge to the West Fargo Aquifer occurs by downward percolation of water from the silt unit in the overlying Lake Agassiz deposits. The amount of recharge depends on the elevation difference between the water table in the silt unit and the artesian head in the aquifer, and on the permeability of the silt and clay units of the Lake Agassiz deposits and the till through which the water must pass.

The water table in the silt unit is, on the average, 47 feet higher than the artesian head in the aquifer below. The water percolating downward from the water table to the aquifer will pass through approximately 65 feet of lake deposits and 50 feet of till. Therefore, the average hydraulic gradient driving percolation is about 47/115 feet per foot.

It is assumed that the lake deposits and the till have a combined average permeability of 0.001 gpd per square foot (Dennis and others, 1949).
On this basis, the quantity of water moving downward to the aquifer is estimated

TABLE 36

PHYSICAL DATA AND AQUIFER TESTS
WEST FARGO AQUIFER

Physical Data

Owner	Location	Depth	Date of Test	Duration (hours)	Pumping Rate (gpm)	Drawdown (feet)	Estimated Drawdown at End of 24 Hours (feet)	Lithology of Aquifer at Well Site
Union Stockyards Company(1)	139-49-6abd	--	07/7/45	22	900	--	--	Sand and gravel.
City of South West Fargo	139-49-8bda	164	11/19/54	23	610	35	35	Medium to coarse sand.
Union Stockyards Company	139-49-6acc	208	10/31/57	5	1,290	28	38	Sand and gravel; coarse gravel and boulders with clay lenses.
City of South West Fargo	139-49-7abb2	204	09/22/60	15.50	775	66	68	Sand and gravel.
Siouxland Dressed Beef Company	139-49-6bda	200	10/05/60	12	1,150	11	17	Fine sand, sand, gravel, and boulders.
Village of West Fargo	139-49-6dcdl	215.50	11/08/63	36	508	17.26	--	Fine to coarse sand.

Results

Location	Transmissivity (gpd per foot)	Thickness (feet)	Permeability (gpd per ft)	Storage Coefficient	Specific Capacity (gallons per minute per foot of drawdown)	Estimated Specific Capacity, 24 Hours (gpm per foot of drawdown)
139-49-6adb(1)	71,100	112	634	3.7×10^{-3}	90 estimated	--
139-49-8bd(2)	40,000	29	1,380	--	17.4	17.4
139-49-6acc(2)	80,000	93	860	--	46.0	34.0
139-49-7abb2(2)	20,000	14	1,430	--	11.5	11.0
139-49-6bda(2)	200,000	107	1,870	--	104.0	67.6
139-49-6dcl(3)	150,500	59	2,552	2.29×10^{-4}	29.4	--

(1)U.S. Geological Survey (Dennis and others, 1949, p. 87).
(2)Estimated aquifer coefficients.
(3)Computed aquifer coefficients.

Source: Klausing (1968)

to be 0.001 x 47/115 x 43,560 x 640 = 11,000 gpd per square mile. The total amount of recharge to the aquifer by movement of water downward from the water table in the silt unit thus amounts to about 1.2 mgd over the 110-square mile area considered (Klausing, 1968).

Prior to development, water was discharged from the aquifer by lateral and upward movement into the adjacent deposits. The amount of water discharged from the aquifer by natural processes has undoubtedly decreased as the number of wells pumping from the aquifer increased. At the present time, it is believed that most of the water leaving the aquifer is discharged by pumping.

A substantial quantity of water is stored in the West Fargo Aquifer. With an estimated porosity of 30 percent and an average saturated thickness of 46 feet, the aquifer would store 110 x 46 x 640 x 0.30 = 972,000 acre-feet, or 317 billion gallons, of water; however, the yield of the aquifer would be much less.

A water-level record spanning about 28 years exists for a well located within 0.3 mile of both the old and new Union Stockyards supply wells.

Use of the old supply well was discontinued about November 1, 1957, and the new well was made operational at that time. The water-level record shows an 85-foot decline from January 1938 to October 1957. A South West Fargo municipal well and the Siouxland Dressed Beef Company supply well were developed in the aquifer in 1960. The water-level record shows an approximate 13-foot decline from November 1960 to November 1962, caused by pumping from the Union Stockyards, Siouxland Dressed Beef Company, and South West Fargo wells.

The hydrograph of an abandoned municipal supply well in West Fargo shows a water-level decline of about 6 feet between August 1962 and August 1965. The general lowering of the water level represents the combined effect of pumping from municipal and industrial wells in Sections 6-8, T139N, R49W.

Water levels measured during the first week of November 1964 were compared with those measured in the same well during the first week of November 1965 (Klausing, 1968). The comparison shows a regional decline of water levels throughout the aquifer (Figure 11). The decline averaged 1.42 feet and is attributed to pumping from industrial and municipal wells in the vicinity of West Fargo. The maximum decline of 2.65 feet was in an observation well near the point of greatest withdrawal.

Based on the estimated recharge, it appears that the safe yield of the West Fargo Aquifer is approximately 0.44 bgy, or 1.2 mgd on an average basis. Water levels in the aquifer have declined historically, and this strongly suggests that the safe yield is being exceeded today on an annual basis.

c. Water Quality

Chemical analyses of water from the West Fargo Aquifer indicate that the water is hard, dissolved solids are high, and average iron content exceeds National Secondary Drinking Water Standards (Table 37).

Sodium is the predominant cation, bicarbonate and chloride the predominant anions. The bicarbonate content ranges from 50 to about 480 mg/l. Analyses of water samples from wells tapping water-bearing sand and gravel lenses in the outlying areas show that the bicarbonate content of these waters has about the same range as the water in the aquifer. However, this is not the case with

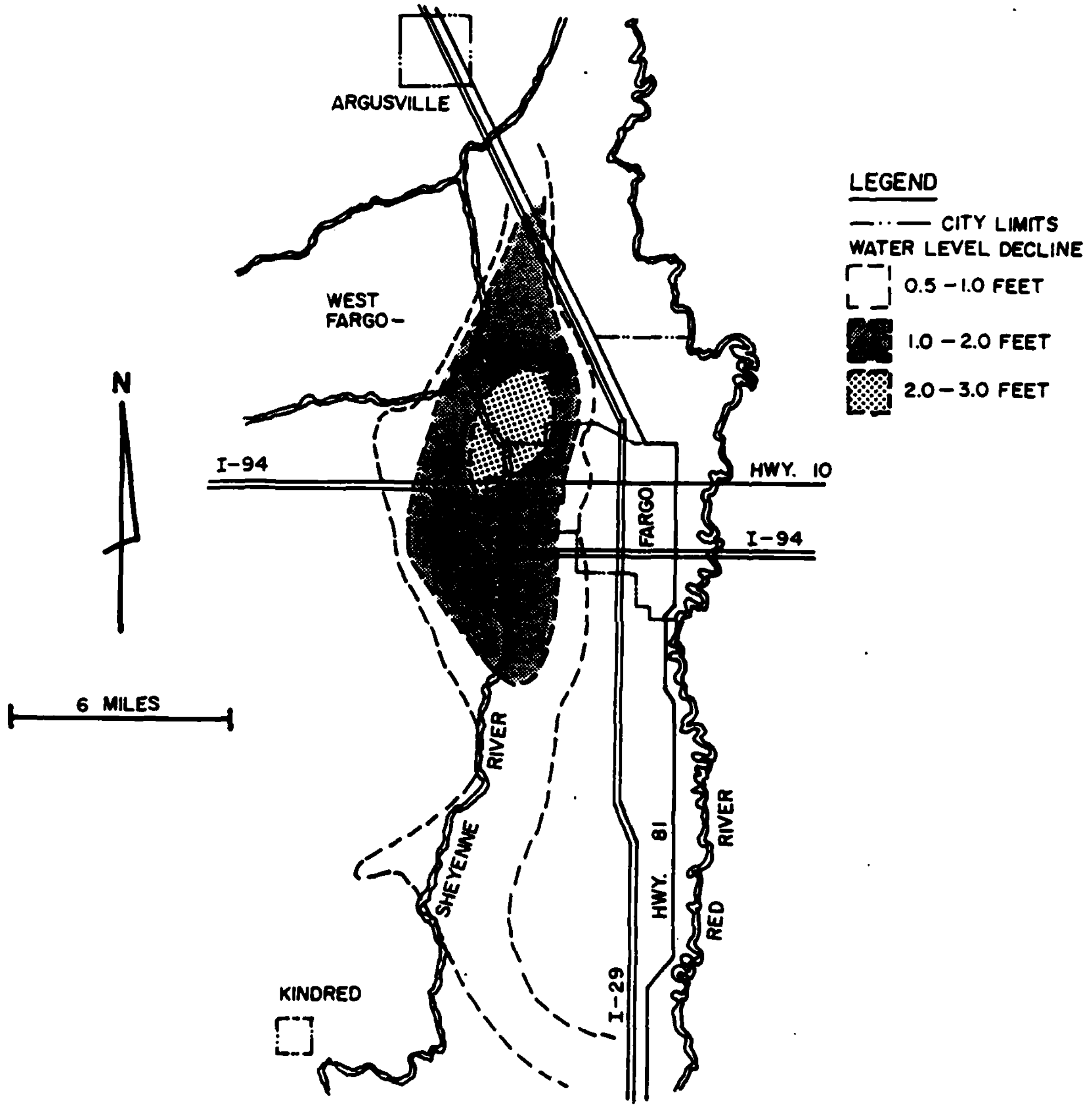

FIGURE 11
Regional Water Level Decline in West Fargo Aquifer
From November 1964 to November 1965
Source: Bulletin 47, North Dakota State Water Commission

TABLE 37

GROUND-WATER QUALITY DATA
WEST FARGO AQUIFER

	Concentration (mg/l)*	
	1965	1982
Silica (SiO_4)	23	26
Iron (Fe)	0.66	0.39
Calcium (Ca)	67	59
Magnesium (Mg)	14	21
Sodium (Na) and Potassium (K)	312	290
Bicarbonate (HCO_3)	377	360
Sulfate (SO_4)	151	140
Chloride (Cl)	310	280
Fluoride (F)	0.5	0.6
Nitrate (NO_3)	5.3	5.5
Hardness as $CaCO_3$	224	234
Total Dissolved Solids	1070	1010

*Union Stockyards well.

SOURCE: Klausing (1968).

chloride. Water samples collected from wells located east of the aquifer generally have a much lower chloride concentration than do those collected from wells west of the aquifer. The general east to west increase in chloride content is accompanied by a transition from a sodium bicarbonate-type water to a predominantly sodium chloride type.

The westward increase in the chloride content of the water probably is due to leakage of saline water from the Dakota Sandstone, which underlies the glacial deposits farther west (Klausing, 1968).

d. Interconnection with Other Aquifers and Nearby Streams

Dennis and others (1949) concluded that the Fargo and West Fargo Aquifers were interconnected. Their conclusion was based on the similarity of water-level fluctuations in wells in the two aquifers. However, water-level trends since 1952 indicate that a good hydraulic connection between the aquifers does not exist.

Although the Fargo and West Fargo Aquifers approach each other closely (Figure 4), there is no geologic evidence to indicate that the aquifers are connected. Disregarding the lake deposits, the material lying between the aquifers consists of till, which contains thin lenses of sand and gravel. These lenses generally occur at different horizons and are considered to be not connected.

The West Fargo Aquifer underlies portions of the Sheyenne River. However, significant hydraulic connection between the aquifer and the river is unlikely because of the thick silt and clay layers above the aquifer.

e. Ability to Meet Local Demand

Water pumped from the West Fargo Aquifer is used to meet municipal and industrial needs in the West Fargo area. Table 38 shows water withdrawn from the aquifer in 1980.

TABLE 38

WATER WITHDRAWAL - WEST FARGO AQUIFER
1980

User	Withdrawal (billions of gallons)
City of West Fargo	0.34
City of Riverside	0.01
Union Stockyards	0.01
Siouxland Dressed Beef Company/ Held Beef	0.14
Cargill	0.05
	0.55

Further development of the West Fargo Aquifer could cause the water levels to decline below the top of the aquifer. Because this aquifer is already being used at or above capacity in the West Fargo area, further development is not recommended.

Artificial aquifer recharge has been considered as a means of extending the ability of the West Fargo Aquifer to meet local demands. An unconfined aquifer was artificially recharged near Minot, North Dakota, until the mid-1970s. This recharge system could be thought of as a natural system, as it did not require pumps to inject water into the aquifer. The system consisted of several 6-foot diameter conduits filled with permeable material that extended from the surface

to the underlying aquifer, located approximately 120 feet below the surface. Floodwater from the Souris River was pooled over these conduits and allowed to percolate into the underlying aquifer.

Where artifical recharge is feasible it is most commonly associated with unconfined aquifers under water table conditions similar to those near Minot. The West Fargo Aquifer, however, is a confined, or artesian, aquifer. The thickness (as much as 200 feet) of the confining bed above the aquifer implies that artificial recharge may not be a feasible alternative. These and other special characteristics of the West Fargo Aquifer require that a detailed study be performed in order to determine the feasibility of artificial recharge.

At the present time there are no North Dakota State rules and regulations that deal directly with artificial recharge. The North Dakota State Water Commission would review any proposed artifical recharge scheme since they would govern the water appropriations associated with the plan. In the event that treated wastewater were proposed for artificial recharge, the North Dakota Health Department would also be involved.

5. West Fargo South Aquifer

a. Location and Extent

There is little available information specifically on the West Fargo South (or Hickson) Aquifer. One source of data is an extensive ground-water study conducted in 1978 and 1979 that sought an alternate source of water for the City of Fargo (Ulteig, 1979). In this study, geophysical reconnaissance and test drilling verify that an extensive aquifer exists south of West Fargo

and that this aquifer may be connected to, or be a part of, the West Fargo Aquifer. The aquifer has been designated as the West Fargo South Aquifer and is shown in Figures 4 and 5.

The aquifer ranges up to 200 feet in thickness and lies in a southeast-northwest configuration, varying from one-half to one and one-half miles in width. Pumping tests indicate the aquifer coefficient of transmissivity is approximately 33,000 gpd per foot and the coefficient of storage is 3.4×10^{-4}.

b. Safe Yield

Based on the results of pumping tests, the aquifer is capable of producing large quantities of ground water (Ulteig, 1979). An accurate determination of the aquifer's safe yield is not possible with presently available data. However, it is believed that the safe yield is on the order of 0.44 bgy (i.e., 1.2 mgd on an average basis).

c. Water Quality

Analyses from test holes suggest that the West Fargo South Aquifer is highly variable in terms of water quality. Table 39 shows chemical analyses of several test holes used in the West Fargo South Aquifer investigation.

d. Interconnection with Other Aquifers and Nearby Streams

There is evidence of interconnection between the West Fargo and West Fargo South Aquifers, as previously noted. The West Fargo South Aquifer partly underlies the Sheyenne River and, perhaps, the Wild Rice River as well. But no available data indicate any significant connection between the aquifer and either river.

TABLE 39

CHEMICAL ANALYSES - TEST HOLES
WEST FARGO SOUTH AQUIFER

Constituent	TH-2	TH-3	TH-4	TH-5	TH-6	TH-7	TH-8	TH-9	TH-10	TH-11	TH-12	TH-14	TH-15	TH-16	TH-17	TH-18
pH	7.6	8.2	7.8	8.0	8.1	80	8.4	8.1	8.4	8.0	8.3	8.3	8.3	8.3	8.3	8.1
Conductivity	980	1270	2750	940	1430	1290	1000	2500	1180	2050	1260	1700	2675	2200	--	214
Total Dissolved Solids	816	1030	2080	1119	1073	1002	845	1897	993	1544	942	1264	1924	1615	1846	172
Iron (Fe)	11.3	0.4	1.02	9.0	0.09	1.09	0.32	3.08	0.48	1.05	1.44	0.75	0.95	1.90	2.70	0.9
Manganese (Mn)	1.4	0.08	0.18	0.2	0.07	0.09	0.08	0.29	0.07	0.13	0.22	0.08	0.22	0.20	0.27	0.1
Calcium (Ca)	70	80	150	230	75	55	75	155	70	125	85	95	135	115	145	145
Magnesium (Mg)	25	24	34.5	67	23.5	18.5	18	36.5	19.5	29	22.5	30.5	56	36	29.5	24.
Total Hardness (as $CaCO_3$)	278	299	517	851	284	214	262	538	255	432	305	363	568	436	484	463
Potassium (K)	8	5.5	7.5	12.5	7.0	6.0	6.5	8.0	6.0	5.5	8.5	5.0	9.0	7.0	12.5	7.0
Sodium (Na)	140	195	495	155	215	215	152	416	191.5	346	180	258	454	366	416	350
Chlorides (Cl)	8	162.5	525	63	235	150	110	480	150	350	100	225	475	275	400	450
Sulfate (SO_4)	139	142	592	156	104	170	101	529	147	384	194	315	555	517	494	422
Total Alkalinity (as $CaCO_3$)	348	344	224	356	338	316	320	222	292	248	288	276	196	244	286	268
Bicarbonate (HCO_3)	425	420	273	434	412	386	373	272	339	303	351	332	239	298	349	327
Nitrate (N)	1.01	1.06	2.99	<1.0	.8	1.23	0.09	0.16	0.04	<1	<1	<1	<1	<1	<1	<1
Fluoride (F)	0.4	0.4	0.5	0.3	0.4	0.5	0.4	0.5	0.4	0.46	0.35	0.45	0.36	0.3	0.3	

Source: Ulteig (1979).

e. Ability to Meet Local Demand

Present known withdrawals from the aquifer include pumpage from three Cass Rural Water Users Association wells (see Chapter III). The estimated total withdrawal is approximately 0.07 bgy (average of 0.19 mgd). Thus it appears that the West Fargo South Aquifer can supply substantially more water than is withdrawn at present. Similar circumstances govern the feasibility of artificial recharge for the West Fargo South and the West Fargo Aquifers. This topic is addressed in the discussion of the West Fargo Aquifer.

6. Moorhead Aquifer

a. Location and Extent

The Moorhead Aquifer is located in the City of Moorhead. The aquifer region consists of isolated sand and gravel lenses within the glacial till. The City of Moorhead has developed two wells in these sand and gravel lenses.

Individual wells penetrating the aquifer yield from less than 100 gpm to as much as 1,000 gpm, depending on the thickness of the sand and gravel lens. The wells serving the City of Moorhead are the largest production wells in the aquifer.

b. Safe Yield

Declining water levels in portions of the aquifer indicate the Moorhead Aquifer is susceptible to overdevelopment by continuous pumping at high rates. Studies by others suggest that the aquifer is incapable of supplying more than 1.2 mgd on a continuous basis. This value is taken as an estimate of the safe yield. It should be noted that the City of Moorhead considers the safe yield to be lower than the stated value, based on the city's well field production. However, the value 1.2 mgd (0.44 bgy) is considered here to represent the capability of the aquifer as a whole.

c. Water Quality

The water quality of the Moorhead Aquifer is satisfactory, with hardness averaging 180-200 mg/l, dissolved solids concentration in the range of 600-800 mg/l, and iron generally greater than 0.50 mg/l. The water is either a calcium bicarbonate or calcium sulfate type.

d. Interconnection with Other Aquifers and Nearby Streams

No known connection exists with another aquifer. In areas where the aquifer is very shallow, there could be an indirect connection with small streams. However, based on the relatively limited recharge, any connection that may exist is minor and does not significantly recharge the aquifer.

e. Ability to Meet Local Needs

The only significant wells penetrating the aquifer are those serving the City of Moorhead. The small yield of these wells does not meet the needs of the City of Moorhead. However, further development of the aquifer appears to be possible.

7. Kragnes Aquifer

The Kragnes Aquifer is a vaguely defined, buried sand and gravel aquifer that appears to be about 30 feet thick. It is overlain by about 200 feet of till and clay. Presently, this aquifer supplies the City of Dilworth, Minnesota, and some industrial, domestic, and stock needs. In order to evaluate its potential for future large-scale production, subsurface investigations will be required. Because the aquifer is thin, has a thick overburden, and has sand and gravel deposits confined in lenses and pockets, large-scale yields do not appear possible. The present wells serving Dilworth have experienced declining water

levels, indicating that the aquifer is unable to yield more than 0.25 to 0.5 mgd on an average basis. The value 0.25 mgd (0.09 bgy) is taken as an estimate of the safe yield. Water from the aquifer contains sodium bicarbonate and is hard. Total dissolved solids concentrations generally exceed 500 mg/l. The iron content is greater than 0.50 mg/l.

8. Sheyenne Delta Aquifer

a. Location and Extent

The Sheyenne delta occupies an area of about 750 square miles, mostly in Richland and Ransom Counties, North Dakota. The areal extent of the delta in Cass County is about 60 square miles; however, only about two-thirds of this area is underlain by permeable deposits. These deposits are mainly in T137N, R52-53W. The delta was formed where the Sheyenne River flowed into glacial Lake Agassiz, which occupied the Red River Valley during the most recent glacial period.

In Cass County, the Sheyenne Delta Aquifer consists of two sand bodies that are separated by a silt bed about 20 feet thick. The upper sand, which is fine to medium, ranges in thickness from 0 to about 50 feet. The lower sand, which seems to be finer grained and silty, ranges in thickness from 0 to about 60 feet. The maximum thickness of the aquifer, including the intervening silt bed, is about 120 feet.

The estimated transmissivity ranges from 1,500 to 36,500 gpd per foot and averages about 20,000 gpd per foot (Klausing, 1968).

Water level fluctuations in the aquifer reflect for the most part seasonal variations in recharge. The abrupt rise of water levels between the latter part of March and the first part of May indicates recharge to the aquifer by infiltration of snowmelt and rainfall. This recharge begins with the spring thaw and continues until May or June. The rise in water levels caused by the recharge appears to be on the order of 5 feet. The subsequent decline of the water levels is a result of discharge from springs, evaporation where the water table is near the land surface, transpiration by crops and other vegetation, and decreased precipitation. Water levels are lowest during January, February, and March, when little or no recharge reaches the aquifer.

b. Safe Yield

The recharge data cited above correspond to a net infiltration rate of 3.05 inches per year. Taken over the entire Sheyenne Delta Aquifer area of 750 square miles (in Richland, Ransom, and Cass Counties), this rate implies a total recharge of 39 bgy. As noted previously, recharge in the Cass County portion of the aquifer is about 2.1 bgy on the same basis.

Recent data developed by the U.S. Geological Survey (Armstrong, 1981) indicate a recharge rate of 7.4 inches per year. This is more than double the estimate given above. In either case, the Sheyenne Delta Aquifer has a tremendous quantity of water available.

For the present study, the safe yield is assumed to equal the conservative recharge estimate of 39 bgy.

c. Water Quality

Limited chemical analyses of water from the aquifer indicate that the water is a calcium magnesium bicarbonate type. The water is very hard, dissolved solids are approximately 500 mg/l, and iron content ranges from 0.3 to 7.2 mg/l (Klausing, 1968).

d. Interconnection with Other Aquifers and Nearby Streams

The Sheyenne Delta Aquifer is not interconnected with any other aquifer.

Little information is available regarding interconnection between the aquifer and streams. The Sheyenne River cuts through the aquifer, and it is known that many springs in the delta area flow into the river. Conversely, if the water table were considerably lowered, the Sheyenne River could then lose water via seepage into the aquifer. Extensive withdrawals from the aquifer from wells near the river could cause the latter to occur. Large-scale development of the aquifer should carefully consider the interrelationships between ground water, surface water, and springs in the delta area.

e. Ability to Meet Local Needs

Many domestic, irrigation, and stock wells are developed in the Sheyenne Delta Aquifer. While no major municipal user exists, a substantial quantity of water is withdrawn annually. The North Dakota State Water Commission monitors well use and has jurisdiction over water withdrawal through a permit system. Table 40 shows the quantity of water withdrawn from the Sheyenne Delta Aquifer.

TABLE 40

REPORTED WATER WITHDRAWALS
SHEYENNE DELTA AQUIFER

Year	Withdrawals: Annual Total (billions of gallons)	Withdrawals: Average Rate (mgd)
1982	0.90	2.5
1981	0.80	2.2
1980	0.61	1.7
1979	0.80	2.2
1978	0.56	1.5
1977	0.30	0.8
1976	0.21	0.6

Current withdrawals represent less than 3 percent of the aquifer safe yield. Thus the Sheyenne Delta Aquifer is easily able to meet current local needs and has a large capacity for future development.

9. Page Aquifer

a. Location and Extent

The Page Aquifer, in the northwestern part of Cass County, extends northward from near the south line of T141N, R54W into Steele County. In Cass County, the aquifer underlies parts of Townships 141-143N, Ranges 53-55W, and has an areal extent of about 155 square miles. The aquifer boundaries are not definitely known; however, the available data indicate that the aquifer probably does not extend beyond the limits shown on Figure 5.

The Page Aquifer is an artesian system confined at the top by deposits of glacial till that range in thickness from 9 to 80 feet.

The aquifer consists of two intervals of sand and gravel that are superimposed in the drift. The upper interval is a buried glaciofluvial deposit consisting of very fine to coarse sand. It ranges in thickness from 0 to 78 feet. The lower interval is a buried outwash deposit consisting chiefly of fine to medium sand. This interval ranges in thickness from 0 to about 50 feet. Generally, the two intervals are separated by about 30 feet of till; however, it is not known if this separation prevails throughout the extent of the aquifer. Test holes penetrating both intervals have indicated a combined thickness of 89 to 129 feet. The average combined aquifer thickness is estimated to be about 30 feet.

A City of Page municipal well was drilled into the lower interval in July 1962. The well penetrated 40 feet of fine sand in the interval 81-121 feet and had a static water level of 23.5 feet. During the development test, the well was pumped for 12 hours at a rate of 230 gpm with a drawdown of 46 feet. With the exception of 1 foot of water level rise during the eighth and ninth hours of pumping, the pumping level remained rather constant at 69.5 feet after the second hour of pumping, suggesting that equilibrium between discharge and rate of flow to the well had been reached. Because the pumping level remained relatively constant after the second hour of pumping, it seems unlikely that there would be any appreciable increase in the drawdown at the end of 24 hours.

Assuming that the drawdown remained near 46 feet, the specific capacity of the well would be 5 gpm per foot of drawdown. On this basis, the coefficient of transmissivity of the aquifer in the vicinity of the well is estimated to be about 10,000 gpd per foot. The estimated coefficient of transmissivity for the aquifer as a whole, based on analyses of drill samples from test holes, ranges from 4,000 gpd per foot to 82,000 gpd per foot (Klausing, 1968).

Based on an average thickness of 30 feet and an assumed porosity of 30 percent, it is estimated that the aquifer stores about 290 billion gallons of water. However, the yield of the aquifer would be much less.

Records show that water levels in wells drilled into the aquifer in 1928, 1951, 1962, and 1965 were comparable (Klausing, 1968). This indicates that there has been no appreciable decrease in storage in the aquifer during the period spanned by these years.

Klausing (1968) has discussed the apparent correlation of water-level fluctuations in three observation wells installed during the latter part of July 1964 (see Figure 12). The first water level measurements were made only a few days after the casings were installed. The leveling off and subsequent decline of the water levels that occurred during the late fall and winter indicate that discharge exceeded recharge and that there was a temporary loss of storage in the aquifer. The rapid rise in water levels in the spring is believed to be the combined result of recharge and compression of the aquifer by water loading on the land surface.

b. Safe Yield

Insufficient data are available to determine the safe yield of the Page Aquifer precisely. An estimate of safe yield based on certain recharge conditions associated with surficial and buried portions of the aquifer follows. The portions of the aquifer exposed at the surface have a greater recharge.

Surficial:	
20 square miles with recharge of 7.4 inches/year	= 2.6 bgy
Buried:	
135 square miles with recharge of 10,000 gpd/square mile	= 0.5 bgy
Estimated Safe Yield	3.1 bgy

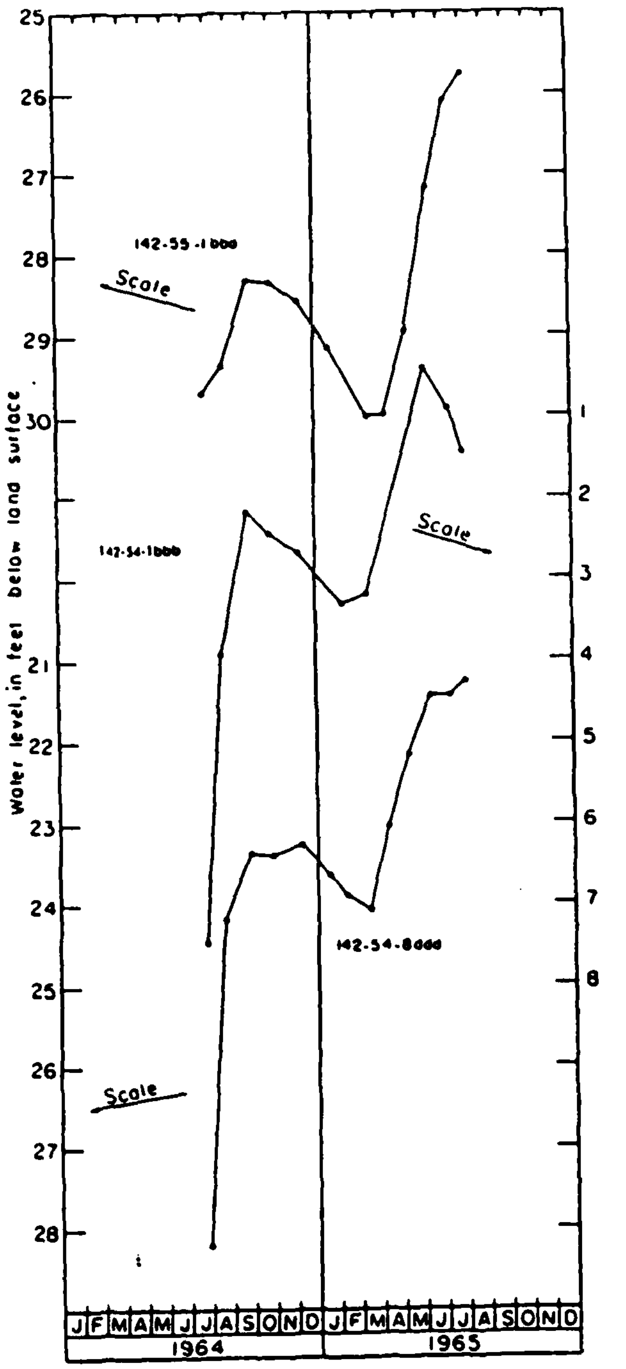

FIGURE 12
Water Level Fluctuations in the Page Aquifer
Source: Bulletin 47, North Dakota State Water Commission

Investigative work is necessary to better define the capabilities of the Page Aquifer, but it appears that the aquifer has the potential for significant development.

c. Water Quality

Analyses of water from the aquifer indicate that the water is predominantly a calcium bicarbonate type. The water is hard; dissolved solids range from 290 to 850 mg/l, and the iron content averages 1.7 mg/l.

d. Interconnections with Other Aquifers and Nearby Streams

No known connection with any other aquifer or nearby streams exists.

e. Ability to Meet Local Needs

The only major wells penetrating the aquifer are those serving the City of Page and the Cass Rural Water Users Association. Many small irrigation/agricultural wells exist, however. Reported withdrawals are shown in Table 41.

TABLE 41

REPORTED WATER WITHDRAWALS
PAGE AQUIFER

	Withdrawals	
Year	Annual Total (billions of gallons)	Average Rate (mgd)
1982	1.13	3.1
1981	0.88	2.4
1980	1.31	3.6
1979	0.69	1.9
1978	0.90	2.5
1977	0.32	0.9
1976	0.09	0.2

At the present time, the Page Aquifer is more than capable of meeting the municipal needs of the City of Page, CRWUA, and the irrigation and other agricultural needs of the adjacent area.

10. Bantel Aquifer

a. Location and Extent

The Bantel Aquifer underlies 9 square miles in the southwest corner of Cass County and extends westward into Barnes County and southward into Ransom County, some 50 miles southwest of the City of Fargo, North Dakota.

The aquifer ranges in thickness from 0 to 80 feet and consists of fine to coarse sand intermixed with gravel. Two test holes penetrated sand and gravel deposits that are 88 and 80 feet thick, respectively; these large thicknesses, when compared with the smaller thicknesses found elsewhere in the aquifer, suggest that the thicker parts of the aquifer may be confined to a narrow channel (Klausing, 1968).

The Bantel Aquifer is confined at the top and bottom by deposits of glacial till. The till overlying the aquifer ranges in thickness from 5 to about 40 feet.

The estimated coefficient of transmissivity ranges from about 8,000 to about 190,000 gpd per foot. However, as most of the test holes penetrated 10 feet or less of sand and gravel, the overall transmissivity of the aquifer probably is less than 8,000 gpd per foot.

Because the aquifer is small in areal extent, it probably does not receive much recharge from the downward percolation of water derived from melting snow or rainfall. Klausing (1968) suggests that one possible source of recharge to the aquifer is in Barnes County where the aquifer intercepts a glacial melt-water channel. The greatest amount of recharge from this source would occur during the spring and early summer when the channel carries runoff from melting snow and rainfall.

Water is discharged from the aquifer naturally by lateral movement into adjacent deposits and by springs where erosion has exposed the aquifer. A small amount of water is discharged by pumping from farm wells.

Available water level data indicate that the hydraulic gradient within the aquifer slopes from west to east.

No long-term water level data are available for this aquifer. The lowest water level measured was 22.75 feet below land surface in January 1965; the highest was 21.3 feet below land surface in April 1965 (Klausing, 1968).

b. Safe Yield

Insufficient data are available to estimate the safe yield of the aquifer. Because of the relatively small areal extent and limited recharge, it is apparent that the safe yield is very limited and not suitable for municipal purposes.

c. Water Quality

Limited water quality data are available. Water samples taken from one observation well indicate that the water is of the sodium sulfate type, is very hard, contains 0.36 mg/l iron, and has a dissolved solids concentration of 1,350 mg/l.

d. Interconnections with Other Aquifers and Nearby Streams

The Bantel Aquifer is not interconnected with any other aquifer. No known interconnection exists with the Maple River, which lies adjacent to and east of the aquifer.

e. Ability to Meet Local Needs

Present development in the aquifer consists of farm and stock wells. The amount of water withdrawn annually by these wells is unknown. Developments requiring large daily withdrawals of water probably would not be feasible because the aquifer is small in areal extent and relatively thin (Klausing, 1968).

Water in the upper sand and in the underlying silt unit is surficial or under water-table conditions. That is, there is no overlying confining layer of less permeable material. The storage coefficient of these two units is therefore probably between 0.01 and 0.30, typical of water table aquifers. Water in the lower sand is probably semiconfined because of the overlying less permeable silt unit. Assuming that the water in the lower unit is semiconfined, the storage coefficient for that unit may be on the order of 0.01 to 0.001.

The aquifer is readily recharged by direct infiltration of water derived from melting snow and rainfall. The greatest amount of recharge to the aquifer occurs during the spring and early summer. It is estimated that the annual recharge in Richland County is about 16 billion gallons (Baker and Paulson, 1967). The area underlain by the aquifer in Cass County is about 13 percent of the aquifer area in Richland County. Assuming similar recharge conditions in Cass County, the annual recharge there would be about 2.1 billion gallons (Klausing, 1968).

Water is discharged from the aquifer by evapotranspiration, lateral movement into adjacent deposits, and pumping. The amount withdrawn to meet rural domestic and stock needs is probably only a small percentage of the total natural discharge.

The hydraulic gradient in the aquifer is to the north and east and ranges from 1 to 2 feet per mile (Klausing, 1968).

The average thickness of the aquifer in Cass County is about 40 feet. Thus, if the average porosity is about 40 percent and the area is 40 square miles, the amount of water stored in the aquifer would be 40 x 40 x 640 x 0.40 = 409,600 acre-feet (133 billion gallons); however, the total yield would be much less.

11. Tower City Aquifer

a. Location and Extent

The Tower City Aquifer is a surficial outwash deposit confined in a partially filled glacial melt-water channel in the vicinity of Tower City, North Dakota. The channel passes through Tower City and extends southeastward to its junction with the Maple River. In most places, the channel and deposits are about one-quarter mile wide.

The thickness of the aquifer is known in only a few places. The municipal well at Tower City penetrated 22 feet of sand and gravel, and one test hole penetrated 9 feet of sandy gravel.

The coefficient of transmissivity of the Tower City Aquifer is estimated to be as high as 22,000 gpd per foot (Klausing, 1968). The water in the aquifer is under water-table conditions; thus, the storage coefficient may be between 0.01 and 0.30.

b. Safe Yield

Most of the recharge to the aquifer occurs during the spring and early summer when excess water from melting snow and rainfall is diverted into the channel. The channel containing the water-bearing deposits drains several square miles in Barnes County. Consequently, most of the recharge to the aquifer in Cass County is derived from precipitation that falls in Barnes County.

As far as is known, there were no wells pumping from the aquifer prior to the development of the public supply well at Tower City in August 1960. Pumpage records for the period extending from August 1960 to December 1963 indicate that the average annual pumpage is about 2.8 million gallons. Safe yield of the aquifer is not known but obviously is very limited because of limited recharge.

c. Water Quality

Water analyses of the Tower City Aquifer indicate that the water is a calcium bicarbonate type, is hard, and has a dissolved-solids concentration of about 500 mg/l.

d. Interconnections with Other Aquifers and with Nearby Stream

Water in the aquifer is under water-table conditions and is not interconnected with any known aquifer. Because the aquifer is relatively shallow, there may be a connection with the Maple River southeast of Tower City.

e. Ability to Meet Local Needs

The supply well at Tower City is the only known development in the aquifer in Cass County. It appears that the aquifer is adequte for local needs but is certainly not capable of large-scale development.

12. Undifferentiated Sand and Gravel Deposits

Undifferentiated sand and gravel deposits that probably were laid down in a glaciofluvial environment are distributed randomly throughout the drift in Cass and Clay Counties. Test holes and wells drilled into the drift commonly penetrate one or more beds of sand and/or gravel at depths from about 20 feet to more than 400 feet. Individual deposits may range in thickness from one foot to 104 feet (Klausing, 1968). The aggregate thickness of separate beds may be as much as 150 feet. The sand and gravel beds are discontinuous and cannot be correlated from one test hole or well to another.

Wells tapping the undifferentiated deposits may yield from less than 1 to about 100 gpm. Pumps installed on most farm wells are piston or submersible types and have capacities ranging from 3 to 10 gpm. Most of these wells can be pumped at maximum capacity for extended periods. Others, however, are reported to go dry or "suck air" after pumping continuously for several hours.

Some of the wells that tap the undifferentiated deposits produce artesian flows. Generally, they flow only a few gallons per minute, but one well drilled to a depth of 276 feet was reported to flow 200 gpm from sand and gravel between 245 and 271 feet (Klausing, 1968). The flowing wells are local phenomena and are not indicative of an extensive body of water-bearing material in which flowing wells could be developed.

Water from the undifferentiated sand and gravel deposits differs widely in chemical character, with the dissolved solids concentration ranging from 182 to 12,400 mg/l. Grouping individual well samples according to water type showed that about 33 percent were sodium bicarbonate, 30.5 percent were sodium

sulfate, 19 percent were sodium chloride, 10.5 percent were calcium sulfate, and 7 percent were calcium bicarbonate type (Klausing, 1968).

Most wells tapping the undifferentiated sand and gravel deposits supply water for rural domestic and stock use; however, the villages of Arthur, Kindred, and Mapleton have developed public supply wells in the deposits.

13. Dakota Sandstone

a. Location and Extent

The Dakota Sandstone underlies all of Cass County except the eastern quarter. It includes all Cretaceous rocks older than the Graneros Shale.

The depth to the top of the Dakota Sandstone ranges from about 300 feet in the eastern part of the area to more than 700 feet in the western part.

The formation underlying that part of the county east of the west line of R52W ranges from 0 to a known thickness of 158 feet (Klausing, 1968). The total thickness of the formation underlying the county west of R52W is unknown.

The Dakota Sandstone consists chiefly of interbedded and/or interlensed silt, shale, loose sand, and sandstone; however, in places it may consist solely of clay or shale. The water-bearing deposits range in texture from very fine to very coarse sand, but very fine to fine sand is predominant. The sand and sandstone range in thickness from 0 to about 50 feet.

The Dakota Aquifer is confined by the Graneros Shale, which in turn is overlain by younger Cretaceous rocks and glacial drift. At places along its eastern edge, the aquifer is in direct contact with glacial till that fills pre-Pleistocene drainages entrenched into the sandstone.

In its eastern extent, the aquifer is underlain by Precambrian crystalline rocks. The nature of the underlying rocks in the western part of the area is unknown.

Most wells drilled through the Dakota Sandstone penetrate one or more water-bearing sand and/or sandstone beds. Hall and Willard (1905) reported that flows were obtained at 287, 325, 378, 404, and 420 feet in a well drilled to a depth of 420 feet in Section 15, T138N, R53W. A test hole drilled to a depth of 467 feet in the northeast corner of Section 27, T139N, R52W, penetrated water-bearing sands in the intervals 367-391 feet and 442-449 feet. Neither sand bed produced a flow. A well drilled only 3 miles to the north penetrated 10 feet of water-bearing sand between 442 and 432 feet. This well was reported to flow at 30 gpm. These examples indicate that the sand beds do not have extensive lateral continuity and cannot be correlated from one well to another (Klausing, 1968).

The estimated coefficient of transmissivity for the aquifer ranges from 2,400 to 11,400 gpd per foot; the higher value was at the public supply well at Buffalo, where the aquifer had an aggregate thickness of 57 feet (Klausing, 1968). No estimates of the average transmissivity of the aquifer can be made because so few data are available. The storage coefficient of the Dakota Sandstone in the Ellendale-Jamestown area has been estimated to be 1.1×10^{-3}.

b. Safe Yield

The aquifer is overlain by thick and relatively impermeable shale of Cretaceous age and by glacial till. Because the water in the aquifer in many parts of the county is under sufficient pressure to flow from wells,

the places where water enters the aquifer must be at a higher altitude; therefore, the recharge area is outside the county. It is also possible that the aquifer receives some recharge by upward movement of water from rocks underlying the Dakota.

Water is discharged from the aquifer by upward and lateral leakage into adjacent deposits. Probably the greatest amount of natural discharge occurs near the eastern limit of the aquifer where the overlying deposits are thin. The rate of natural discharge has undoubtedly decreased over the years because of the large number of flowing wells developed in the aquifer since the later 1800s.

As of 1963 there were at least 326 flowing wells in Cass County. Most of these wells are allowed to flow continuously and serve as a source of supply for rural domestic and stock needs. The annual discharge of water from the aquifer through wells is estimated to be in excess of 582 million gallons.

The piezometric surface slopes from west to east, but the data are inadequate to determine the hydraulic gradient.

Artesian pressure in the Dakota Aquifer and well yields began to decline soon after the first wells were drilled and have declined ever since. From various reports, Klausing (1968) concludes that the piezometric surface in the vicinity of Buffalo declined 164 feet in the 56-year interval between 1909 and 1965.

c. Water Quality

Water from the Dakota Sandstone is highly mineralized but is used extensively in some areas because adequate supplies of more suitable water are not available.

The dissolved solids content of water samples from the Dakota ranges from 2,680 to 4,060 mg/l. Most of the water is a sodium sulfate type; however, some of the water is a sodium chloride type. The sulfate-type water is hard, and the sodium chloride type may be either hard or soft.

The average concentrations of boron, fluoride, and silica in water from the Dakota are, respectively, 3.3, 2.9, and 8.2 mg/l.

d. Interconnection with Other Aquifers and Nearby Streams

No direct connections exist with other aquifers or streams. However, in the eastern portion of the Dakota Sandstone, the glacial till lies directly above the sandstone and, therefore, an indirect connection with the Fargo and West Fargo Aquifers is likely.

e. Ability to Meet Local Needs

The Dakota Sandstone is highly mineralized and generally unsuitable for most uses except stock watering. As such, the aquifer is not used municipally and should not be relied upon for municipal supply.

14. Other Bedrock Aquifers

The Dakota Sandstone is the only bedrock unit within the study area that is known to yield water to wells.

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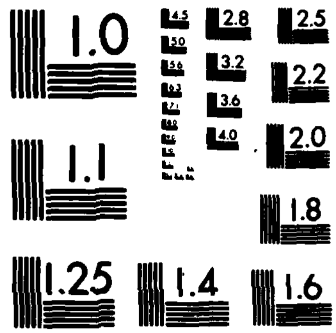


MICROCOPY RESOLUTION TEST CHART
DARDS-1963-A

V. PROJECTED WATER DEMANDS

Water demand projections were made individually for all 18 study area communities for the years 1990, 2000, and 2030. Demands for year 1990 were included to furnish communities with information to aid them in formulating their own immediate future plans. For the purposes of this study, the focus is the projected year 2000 and year 2030 demands.

Demands are measured several ways: average annual daily use, maximum daily use, and peak hour use. Average annual and maximum daily use are design criteria used in the present study for developing preliminary facilities' cost estimates. Peak hour use estimates could be used by local planners in formulating detailed facilities' designs at a later date.

Water demands for the larger communities of Fargo, Moorhead, and West Fargo are presented in Tables 42-44. (Dilworth is not included here because it did not have adequate detailed water use data available.) These demands are based on disaggregated water use information. Table 45 presents aggregated demand projections for the remaining communities. These demands are projected in aggregate based on per capita water consumption.

A. DISAGGREGATED WATER DEMAND DATA

The larger communities have disaggregated water demands that are divided into metered and unmetered use. Metered use includes residential, commercial, and industrial sectors. Unmetered use includes unaccounted-for and public sector use, as well as process water used in water treatment. Appendix A displays water use values for individual components of each of the major user sectors.

TABLE 42

SUMMARY OF DISAGGREGATED WATER DEMAND PROJECTIONS (mgd)
CITY OF FARGO

	YEAR 1990			YEAR 2000			YEAR 2030		
	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour
METERED USE:									
Residential	3.38		33.12	3.64		35.67	4.72		46.26
Commercial	4.02		24.22	4.38		26.69	5.61		35.84
Industrial	0.72		0.82	0.87		0.96	1.11		1.22
Subtotal:	8.12			8.89			11.44		
UNMETERED USE:									
Unaccounted-for and Public	3.09			3.38			4.35		
Subtotal:	11.21	25.56		12.27	27.98		15.79	36.00	
Water Treatment Process Water	1.12	1.12		1.23	1.23		1.58	1.58	
MUNICIPAL TOTAL:	12.33	26.68		13.50	29.21		17.37	37.58	

NOTE: Maximum day prediction based on historic relation between average annual use (excluding filter backwash) and maximum day.

Unaccounted-for water use estimated from historical data to be 38 percent of metered use.

Water treatment process water estimated from historical water utility pumping records to be 10 percent of other total use. Though not a consumptive use, process water represents a significant demand for clean river water that is required for safe operation of the facility. For this reason, Fargo's process water demand is included in this table.

TABLE 43

SUMMARY OF DISAGGREGATED WATER DEMAND PROJECTIONS (mgd)
CITY OF MOORHEAD

	YEAR 1990			YEAR 2000			YEAR 2030		
	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour
METERED USE:									
Residential	1.76		17.25	1.93		18.91	2.16		21.17
Commercial	1.41		8.19	1.63		9.72	1.92		11.83
Industrial	1.59		1.75	1.70		1.87	1.83		2.01
Subtotal:	4.76			5.26			5.91		
UNMETERED USE:									
Unaccounted-for and Public	0.43			0.47			0.53		
MUNICIPAL TOTAL:	5.19	10.38		5.73	11.46		6.44	12.88	

NOTE: Maximum day prediction based on historic relation between average annual use (excluding filter backwash) and maximum day.

Unaccounted-for water use estimated from historical data to be 9 percent of metered use.

Water treatment process water represents negligible consumptive use in Moorhead as a result of conservation practices in the water treatment plant.

TABLE 44

SUMMARY OF DISAGGREGATED WATER DEMAND PROJECTIONS (mgd)
CITY OF WEST FARGO

	YEAR 1990			YEAR 2000			YEAR 2030		
	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour
METERED USE:									
Residential	0.60		3.50	0.73		4.25	1.05		6.09
Commercial	0.39		3.01	0.53		4.10	0.88		6.92
Industrial	0.03		0.03	0.03		0.03	0.04		0.04
Subtotal:	1.02			1.29			1.97		
UNMETERED USE:									
Unaccounted-for and Public	0.10			0.13			0.20		
MUNICIPAL TOTAL:	1.12	2.72		1.42	3.45		2.17	5.27	

NOTE: Maximum day prediction based on historic relation between average annual day and maximum annual day.

Unaccounted-for water use estimated from historical data to be approximately 10 percent of metered use.

TABLE 45

SUMMARY OF AGGREGATED WATER DEMAND PROJECTIONS (mgd)
OTHER COMMUNITIES

	YEAR 1990			YEAR 2000			YEAR 2030		
	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour	Average Annual	Maximum Day	Peak Hour
MUNICIPAL SYSTEMS:									
Dilworth	0.229	0.458	0.896	0.254	0.508	0.995	0.349	0.698	1.360
Glyndon	0.107	0.214	0.458	0.110	0.220	0.470	0.118	0.236	0.506
Sabin	0.073	0.146	0.335	0.085	0.170	0.395	0.124	0.248	0.529
Riverside	0.052	0.104	0.391	0.052	0.104	0.393	0.065	0.130	0.399
Harwood	0.047	0.094	0.326	0.054	0.108	0.373	0.075	0.150	0.520
Horace	0.033	0.066	0.436	0.036	0.072	0.480	0.059	0.118	0.459
CASS RURAL:									
Mapleton	0.026	0.052	0.297	0.028	0.056	0.320	0.056	0.112	0.416
Frontier	0.011	0.022	0.220	0.012	0.024	0.230	0.014	0.028	0.230
Argusville	0.010	0.020	0.210	0.010	0.020	0.210	0.010	0.020	0.210
North River	0.006	0.012	0.148	0.008	0.016	0.186	0.018	0.036	0.247
Briarwood	0.006	0.012	0.180	0.006	0.012	0.180	0.006	0.012	0.180
INDIVIDUAL SYSTEMS:									
Reile's Acres	0.013	0.026	0.220	0.013	0.026	0.220	0.013	0.026	0.220
Prairie Rose	0.010	0.020	0.137	0.011	0.022	0.159	0.025	0.050	0.245
Rustad	0.004	0.008	0.094	0.004	0.008	0.101	0.004	0.008	0.108
Kragnes	0.003	0.006	0.065	0.003	0.006	0.065	0.003	0.006	0.065

NOTE: Maximum day use estimated to be 2 times the annual average use (Fair et al., 1966).

Average annual use was projected using historic per capita water use data and Phase 1 Part 1 population projections.

Peak hour use based on peak demand of 1.3 to 5.0 gpm per residential connection, depending on the number of residences served (Ameen, 1965).

Projected demands are derived assuming that one water system serves each entire community.

The development of disaggregated demands for the larger communities is a data-intensive process. First, information is gathered regarding parameters directly related to water consumption, and demands are developed and calibrated for the base year 1980. Then, demands in future years are projected for each component parameter of each major user sector using appropriate indices such as population, employment, and housing data. The development of these data and the assumptions involved in their use are described in the following for each water use sector.

1. Residential Sector

Residential average annual water use is the product of the number of single family residences and an average historic use-per-unit coefficient. The base year number of single family residences is assumed to be equal to the number of residential service connections in 1980, based on utility records. The future number of residences includes projected additional single family homes. Total numbers of single family residences for base year 1980 and projection years 1990, 2000, and 2030 are shown in Table 46. The number of additional homes is calculated using a multi-step process based primarily on adopted municipal population projections.

The first step involved in calculating the total number of new housing units is to project the population per household in each projection year. This value is determined for Fargo and West Fargo by extrapolation of historic census data. The Moorhead value is derived from information in Housing for the 80's (City of Moorhead, 1980). The total number of housing units is then calculated by dividing the projected population by the projected population per household.

TABLE 46

HOUSING DATA FOR WATER DEMAND PROJECTIONS

Housing Type	Number of Housing Units			
	Year 1980	Year 1990	Year 2000	Year 2030
FARGO				
Single Family	13,042	14,879	16,030	20,781
Multiple Family	10,755	13,816	15,734	23,654
Mobile Home	1,419	1,623	1,751	2,279
Total Housing Units	25,216	30,318	33,515	46,714
MOORHEAD				
Single Family	6,270	6,654	7,277	8,150
Multiple Family	3,915	4,616	5,757	7,354
Mobile Home	395	479	616	808
Total Housing Units	10,580	11,749	13,650	16,312
WEST FARGO				
Single Family	2,155	2,630	3,188	4,572
Multiple Family	1,163	2,027	3,040	5,558
Mobile Home	442	543	661	955
Total Housing Units	3,760	5,200	6,889	11,085

Then the total additional housing units are partitioned among single-family, multiple-family, and mobile-home housing types according to information from MCOG (1978) and City of Moorhead (1980).

Maximum-day and peak-hour residential use for Fargo and Moorhead are based on ratios of average annual demand to maximum day demand and of average annual demand to peak-hour demand developed from MAIN II computer runs. This computer program was developed by Hittman and Associates for the U.S. Army Corps of Engineers in 1969 to calculate municipal and industrial water demands. The program is based on work done by Johns Hopkins University throughout the 1960s. West Fargo maximum-day and peak-hour demands are calculated from regression equations also based on the Johns Hopkins work, in this case, developed by Laksham (1976).

Several assumptions are involved in this process in addition to the population projections. The most important of these is that per capita water use is assumed to continue to increase, since population per household will continue to decline while water use per household remains constant.

2. Commercial Sector

Total commercial sector water demands represent the sum of the individual components' demands. Component demands are calculated as the product of the number of parameter units and a use-per-unit coefficient. Base-year data were obtained from various Federal and local government publications, personal interviews, and the phone directory yellow pages. The particular parameters and their respective values are shown in Appendix A. Coefficients responsible for the majority of the calculated water uses are based directly on year 1980

municipal utility data. The remaining coefficients are from Hittman and Associates (1969), MAIN II System computer runs, Arthur D. Little, Inc. (1983), Clark et al. (1971), AWWA (1975), Ameen (1965), and Laksham (1976).

Portion 1 of the commercial sector is composed mainly of service sector businesses. Accordingly, adjusted OBERS-projected services employment data were used to forecast this portion's water use. These OBERS values are shown in Table 47.

Portion 2 of the commercial sector contains components that were projected independently with closely related parameters for which better data existed. Retail demand is estimated from OBERS-projected retail employment data (see Table 47), and school and college needs are based on enrollment projections. Multiple-family and mobile-home demands were calculated using the projected number of housing units developed from population projections, along with other residential sector information. (As noted in Chapter III, multiple-family and mobile-home demands are classified with commercial demands in most utility records and in this study.) Housing unit use-per-unit coefficients were developed from historic utility data.

Commercial sector calculations involve several important assumptions. Housing-related components of the commercial sector data rely on the population projections. Multiple-family and mobile-home housing units are major water users, determined essentially from population projections adopted by area communities at the onset of the study. Implicitly, the employment data for Moorhead and Fargo assume the existing urban area will maintain its share of the State's economy because the OBERS employment data maintain a constant

TABLE 47

EMPLOYMENT DATA FOR PROJECTING RETAIL AND PORTION 1
COMMERCIAL WATER DEMAND

Location	Employment Year 1980	Year 1990	Year 2000	Year 2030
TOTAL SERVICES				
North Dakota Portion SMSA	13,028	16,805	17,981	20,801
Fargo City	9,000	11,595	12,407	14,353
RETAIL TRADE				
North Dakota Portion SMSA	10,606	11,971	12,963	13,940
Fargo City	7,652	8,739	9,463	10,176
TOTAL SERVICES				
Minnesota Portion SMSA	4,323	5,495	6,229	7,170
Moorhead City	2,895	3,737	4,236	4,876
TOTAL TRADE				
Minnesota Portion SMSA	4,760	5,578	6,039	6,484
Moorhead City	2,143	2,510	2,718	2,918

NOTE: Employment projections for Fargo-Moorhead Standard Metropolitan Statistical Area (SMSA) from OBERS employment data (Bureau of Economic Analysis, 1980).

Fargo data from Fargo Job Service records for 1980 and past years used to develop ratios for projections.

Moorhead data from Moorhead Job Service records for 1980 and past years used to develop ratios for projections.

Total trade data is shown for Minnesota Portion SMSA and Moorhead City. This data was used to accommodate the classification system of the Moorhead Job Service.

relationship between the SMSA and the State. Using one projection index for portion 1 of the commercial sector assumes that the existing mix of components will remain constant throughout the projection period. In West Fargo, portion 1 of commercial water use represents relatively small water users. The growth rate of this particular portion was estimated to be 10 percent per decade.

3. Industrial Sector

Industrial sector water demands for the larger communities represent the sum of the demands of individual industrial categories. Water use within each category is the product of the number of factory employees and a use-per-employee coefficient. Coefficients based on year 1980 utility data account for better than half of the larger communities' industrial water use. Remaining coefficients are from Hittman and Associates (1969).

Base year industrial employment is determined mainly from the Fargo-Moorhead Directory of Manufacturers (Fargo-Cass County Industrial Development Corporation, 1982). Projected Fargo and Moorhead employment is based on OBERS industrial employment projections (see Table 48). Because no specific information is available for West Fargo, industrial growth was estimated to be 10 percent per decade.

The use of OBERS employment projections implies that area industrial growth is proportional to Minnesota or North Dakota industrial growth, as previously discussed for the commercial sector data. The projected industrial mix is assumed to remain similar to the existing mix.

TABLE 48

EMPLOYMENT DATA FOR PROJECTING INDUSTRIAL WATER DEMAND

Location	Industrial Employment			
	Year 1980	Year 1990	Year 2000	Year 2030
North Dakota Portion SMSA	4,407	5,662	6,881	8,706
Fargo City	2,735	3,963	4,817	6,094
Minnesota Portion SMSA	1,481	2,090	2,236	2,404
Moorhead City	1,399	1,881	2,012	2,164

NOTE: Employment projections for Fargo-Moorhead Standard Metropolitan Statistical Area (SMSA) from OBERS employment data (Bureau of Economic Analysis, 1980).

Fargo City data from Fargo Job Service records for 1980 and past years used to develop ratios for projections.

Moorhead City data from Moorhead Job Service records for 1980 and past years used to develop ratios for projections.

4. Unaccounted-for and Public Sector

Unaccounted-for water use primarily includes water lost from the distribution system through leaks and breaks. Public water use includes water used in fire protection, street cleaning, parks, and public buildings. Because both unaccounted-for and public use are unmetered, they are often lumped together. Their total use is usually calculated as the remainder of the master meter reading at the water supply source less the total metered use. Therefore, the unaccounted-for and public use sector is a sink for all meter measurement errors. These errors average out over time so unaccounted-for and public use were calculated as an average value using 10 years of historic utility records for Fargo and Moorhead. The West Fargo use was approximated from 3 years of data. It is assumed that the percentage of future unaccounted-for water remains equal to the historic average levels. Fargo water treatment process water was predicted as a fraction of other use based on historic water utility records (see Chapter III).

B. AGGREGATED WATER DEMAND DATA

Water demands for the rural communities in the study area are primarily those developed in Phase 1, Part 1 of this study. Community water-use data were collected from study questionnaires received by all municipalities, as well as personal communications. Projected demands were then forecast using historical per capita consumption and adopted community population projections. Although these demands are projected in aggregate, they are essentially residential demands and can often be treated as such without loss of information. Riverside is a noted exception because its industrial sector water use recently has expanded to compose up to 59 percent of the city's average monthly water consumption. However, because of the limited information available, demands for Riverside were also projected in aggregate.

VI. ENVIRONMENTAL RESOURCE PROBLEMS AND NEEDS

A. AQUATIC RESOURCES

Human activities contribute to the degraded water quality of the Red River and its tributaries in the study area. Elevated levels of pollutants from industrial, municipal, and agricultural sources adversely affect the fish and aquatic resources.

Major industrial sources of water pollution are food processors; sugar beet refineries; potato processors; poultry and meat packers; and milk, cream, and cheese processors. The major waste treatment problems are those from the sugar beet and potato processors. These wastes are produced seasonally at times of low streamflow and low biological activity in winter. Sugar wastes discharged into river water at times of low flow will cause an intense concentration of pollutants and a reduction in dissolved oxygen.

Municipal effluent reduces the capacity of rivers to assimilate wastes during periods of low flow. This can create a low concentration of dissolved oxygen and can cause serious bacterial pollution.

The control of nutrients in runoff entering all rivers would require changes in the land-use practices of upstream watersheds. Runoff from farmlands and livestock feedlots adds high levels of orthophosphates, ammonia, nitrite, and nitrate-nitrogen. Phosphorus and nitrogen in large quantities in natural waters can lead to nuisance algal blooms. These blooms eventually decompose and can cause oxygen depletion fatal to desirable fish species and other aquatic life. Ammonia results from the decomposition of organic matter. The toxic component of ammonia is un-ionized ammonia. It will increase its toxicity to fish when there is a decrease in dissolved oxygen.

Water and wind erosion of farmland has caused sedimentation problems in the rivers. Turbidity levels are unacceptable in many reaches of the rivers. Bottom substrates have been silted over reducing the productivity of habitat and the species composition of aquatic life. Land treatment measures need to be implemented that would help retain soil and water on land and retard runoff and silt deposition into the rivers.

The fishery in the study area is a major resource, and maintenance of this resource is of prime importance. The Tennant Method is widely used by Federal and State natural resources agencies for determining in-stream flow requirements for fish. This method uses percentages of mean annual flow as measures of in-stream flow needs for aquatic organisms. Sustaining 60 percent of the average annual flow for the Sheyenne and Red Rivers would provide excellent to outstanding habitat for fish and other aquatic species. U.S. Geological Survey flow data for these two rivers is summarized in the General Re-evaluation of the Sheyenne River (U.S. Army Corps of Engineers, August 1982). Based on these data, needed flows equal 102 cfs in the Sheyenne River at West Fargo and 336 cfs in the Red River at Fargo.

To sustain good survival habitat for fish, 30 percent of the average annual flow for the Sheyenne and Red Rivers, or 51 cfs and 168 cfs, respectively, are needed. This amount of flow would allow for adequate fish production and movement; however, invertebrate organisms and fish populations would be adversely affected over an extended period of time.

Ten percent of the average annual flow for the Sheyenne and Red Rivers, or 17 cfs and 56 cfs, respectively, would allow a limited survival for fish resources. These flows would sustain only a short-term survival for most fish species.

Further studies should be made to determine adequate in-stream flow needs of particular fish and wildlife resources in the study area. Alternate methods of establishing minimum in-stream flows that look at seasonal variations in streamflows and the needs of specific fish species should be considered. Future studies would need to be correlated to current and projected water demands for residential, commercial, industrial, and agricultural uses. Physical and legal circumstances of flows should first be looked at for each of the streams in the study area.

Information on water quality problems of the Red River and its tributaries should be updated. This would aid in identifying pollutants that limit or threaten fish resources. Ways to correct water quality problems that are harming aquatic life could then be studied and, if feasible, acted on.

B. WILDLIFE RESOURCES

The clearing of trees, intensive drainage of wetlands, and conversion of woodlands, grasslands, and wetlands to other land uses have significantly reduced these habitat types. The effect on wildlife resources has been detrimental and decreased both population densities and species diversity in the study area.

The narrow strips of trees and shrubs along the Red River and its tributaries essentially provide the only remaining habitat suitable for wildlife. Agricultural and urban encroachment into many parts of these green corridors has caused the removal of riparian plants almost to the water's edge.

Continual destruction and degradation of remaining habitat will result in the eventual elimination of the basic life requirements necessary for wildlife survival. As such, woodland, grassland, and wetland areas have significant

wildlife values that should be re-established, restored, or enhanced within the study area.

The development of an area-wide or basin-wide land-use plan would be very beneficial and would guide future development. This plan should include natural resources and their recreational uses. A plan for the management, restoratioin, or enhancement of fish and wildlife habitat resources and a supply and demand analysis of hunting and fishing values are needed.

The fish and wildlife resources of the study area are important in determining the implementability and acceptability of water supply alternatives. The above discussion points out some concerns that community planners should be aware of when evaluating plans to meet future water demands. (See the "Social and Environmental Inventory" of the urban study for additional information.)

VII. IDENTIFICATION OF MUNICIPAL WATER SUPPLY PROBLEMS

A. GENERAL

The objective of this evaluation is to determine whether sufficient water of acceptable quality will be available to each community in the years 2000 and 2030. Water shortages are determined by comparing available water supplies and municipal demands. Following a discussion of methodology, this chapter describes water shortages for each community, outlines additional water treatment and distribution facilities needed, and discusses potential supply sources.

Municipal water supply problems were identified by evaluating the ability of a community's facilities and sources to meet projected demands under "no-action" conditions. The no-action analysis assumes no changes in existing facilities. These conditions are used solely for the purpose of identifying water supply problems; they, of course, do not represent a realistic future scenario. However, water supply problems associated with no-action conditions do provide good information about the relative size and timing of required water supply developments.

A more realistic basis of analysis is that a community faced with a severe water shortage will find some means of supply. Most likely, without consideration of plans in this report, communities would develop new sources on an as-needed basis. This type of development fails to fully consider regional or subregional options that might minimize cost and other adverse impacts. Community actions under these circumstances are considered "without project" conditions. In Chapter VII, a water supply alternative is developed to address without project conditions.

Water facility evaluations were made on a community-by-community basis to determine water shortages and to make preliminary judgments about the adequacy of municipal water supply facilities. Peak daily shortages were determined by comparing the maximum daily municipal demand plus a fire-flow requirement with the municipality's firm-yield water supply plus 80 percent of the treated water storage. Fire-flow requirements were determined from Insurance Services Office guidelines (1980) and the National Board of Fire Underwriter's Formula (Fair et al., 1966). The firm yield is the yield of supply facilities with the largest pump out of service.

Peak daily shortages for communities served in bulk by the Cass Rural Water Users Association are more difficult to determine, since no estimates of maximum supply rates are available from the CRWUA. Therefore, for this evaluation, maximum delivery rates for Mapleton, Argusville, and Briarwood were assumed to be the maximum CRWUA allotted supply rate. The fire-flow requirement was dropped for Briarwood, Harwood, Frontier, Reile's Acres, and North River since fire protection is supplied by Horace or West Fargo Fire Department trucks. The CRWUA serves Frontier and North River on an individual homeowner basis. Water facility evaluations were not feasible for these and other individually self-served communities since data would have to be collected from each homeowner.

For the larger communities, water shortages were also evaluated for periods beyond the maximum day using mass (cumulative flow) curves to compare supplies and demands. The procedure determines the maximum amount of water required to bridge a drought associated with 50-year low streamflows.

The supply mass curve considers the amount of available streamflow, ground-water production, and treated water storage available with time. The streamflow component represents a drought in which the lowest streamflows occur initially,

and flows gradually increase throughout the drought period. Streamflow supplies were determined using the 50-year low streamflows derived in Phase 1 of this study for year 2030 conditions. Year 2030 streamflows were selected for use in both year 2000 and 2030 situations since the operation of upstream reservoirs affects streamflows in the Sheyenne and Red Rivers. The Phase 1 results indicated the importance of these effects in an unexpected way. Flow-frequency curves for stations on the two rivers showed short duration drought flows that were higher under year 2030 demand conditions than under 1980 conditions. The higher flows reflect streamflow regulation that would be geared to higher demands under year 2030 conditions. The important implication is that year 2030 streamflow statistics should reasonably represent the amount of flow that could be available from the present at least through the year 2030. Thus, the approach to determining year 2000 supply shortages for the Sheyenne and Red Rivers entails use of the supply mass curves developed in Phase 1 for year 2030 conditions.

The available ground-water supplies were assumed to be limited by volumetric safe yields on an annual basis. High withdrawal rates were allowed on a short-term basis to help bridge drought periods. In such cases, however, withdrawal rates at other times were required to be reduced to ensure that the annual volumetric safe yield would not be exceeded.

Available treated water storage was assumed to be fully utilized during the first day of a drought period.

The demand mass curve is based on the sum of municipal, agricultural, minimum required in-stream flow, and self-served industrial needs. Two minimum in-stream flow cases were considered. The mass curve analysis (discussed below)

used minimum flows of 7 cfs in the Red River and 3 cfs in the Sheyenne River based on recommendations in the Souris-Red-Rainy River Basins Comprehensive Study. The 7- and 3-cfs criteria will hereafter be referred to as the SRR (Souris-Red-Rainy) criteria. The second criteria (hereafter referred to as the Tennant criteria) provides for suspension of municipal withdrawals whenever withdrawals would reduce streamflows below the 30-percent threshold recommended by Tennant for good survival habitat for fish.

Municipal demands were assumed to vary with time. As for streamflow supplies, the worst conditions (in this case, maximum municipal demands) were assumed to occur initially, with conditions gradually moderating thereafter. For this analysis, municipal-demand peaking factors were derived from historical utility data for maximum day, maximum week, maximum month, etc. Non-municipal demands were assumed to remain constant with time.

The difference between the mass demand curve and the mass supply curve indicates the additional water supply required. This supply can be satisfied by additional ground-water sources, surface water sources, or a combination of the two. A possible surface-water source is additional reservoir storage. The additional storage required to meet a deficit is the minimum upward translation of the supply curve that makes cumulative supplies equal to or greater than cumulative demands at all points. The additional ground-water sources required to satisfy the deficit are determined from the minimum increased slope of the mass supply curve (mass/time = flow rate) which makes cumulative supplies equal to or greater than cumulative demands at all points. An infinite combination of both increased storage and increased ground-water sources also exists. From an economic standpoint, the optimum mix is the one that minimizes annualized or total present value costs.

B. FARGO

Fargo has access to available flows in both the Red and Sheyenne Rivers. The streamflow values used reflect the operation of Lake Ashtabula and Orwell Reservoir to meet Fargo-Moorhead water needs, as previously discussed (see Chapter IV). However, the sources of supply must be shared with other surface-water users, including Moorhead, minimum in-stream flow requirements, various self-served industries, and agriculture.

Year 2000 average annual municipal demand is projected to be 13.5 mgd, and maximum daily demand to be 29.21 mgd. Under the no-action alternative, coincidental 7-day, 50-year low-flow events in the Red and Sheyenne Rivers could cause the City of Fargo to experience a peak daily deficit of 15.31 mgd. The municipal facilities themselves would be capable of meeting these needs, if adequate water supplies were available and if the wastewater treatment plant could be pushed approximately 20 percent beyond its average annual design capacity.

By the year 2030, the average annual municipal demand is forecast to increase to 17.37 mgd. The municipal maximum day demand would increase to 37.58 mgd. Because of supply limitations, peak daily deficits would be 23.68 mgd. If adequate flows were available, the existing transmission facilities could still furnish the peak demand rates on the maximum day. However, the distribution system would need another 2.7 million gallons of storage, the wastewater treatment plant's average capacity would have to be increased 100 percent from its existing 9 mgd capability, and the water treatment plant would have to be expanded to meet peak day demands.

To meet Fargo's projected deficits, new sources of supply need to be developed. Potential sources include the West Fargo South Aquifer, Sheyenne Delta Aquifer,

Garrison Diversion Project, Buffalo Aquifer, as well as reservoirs on the Red and Sheyenne Rivers.

C. MOORHEAD

The City of Moorhead has developed its existing well fields in the Moorhead and Buffalo Aquifers to their maximum yields, and the water supply available from the Red River during drought is limited.

Moorhead's year 2000 average annual demand is forecast to be 5.73 mgd and the maximum daily demand to be 11.46 mgd. Supply limitations could cause peak daily shortages of 2.15 mgd. However, the existing municipal facilities would be capable of meeting the maximum demand rates, if adequate water supplies were available from existing sources. An additional treated water storage of approximately 0.53 million gallons would also be required.

By the year 2030, average daily demands will increase to 6.44 mgd and maximum daily demands to 12.88 mgd. Supply limitations could cause peak daily shortages of 3.57 mgd. If adequate water supplies are available, existing municipal water facilities could still meet peak demand rates on the maximum day, though 2.21 million gallons of additional storage would be required to supply the volume of water needed on the maximum day. The projected average annual demands also exceed the wastewater treatment plant capacity by 0.44 mgd, or approximately 7 percent.

Potential sources that could supply Moorhead with additional water include the Buffalo Aquifer, the Garrison Diversion, and reservoirs on the Red River as individual storage sites or components of subregional systems.

D. WEST FARGO

The City of West Fargo has just completed the development of a new well in the West Fargo Aquifer. However, historical water level data strongly suggest the

safe yield of this aquifer is presently being exceeded on an annual basis. Under these conditions it can be expected that in the future there will be increasing drawdowns, reduced well yields, higher pumping costs and eventually the need to find other sources of water. The shortages described below consider existing withdrawals to continue. Therefore, estimated shortages represent minimum values since future well yields can be expected to decrease.

West Fargo's year 2000 average annual water demand is projected to be 1.42 mgd and the maximum daily demand 3.45 mgd. Considering fire-flow demands and available treated water storage, supply limitations could cause peak daily shortages of 0.76 mgd.

By the year 2030, West Fargo's average annual demand is forecast to increase to 2.17 mgd and maximum day demand to 5.27 mgd. The peak daily shortage could reach 2.58 mgd. The wastewater treatment capacity, including the two lagoons being added at present, would be exceeded by more than 200 percent. Even if adequate water supplies were available, additional facilities would be needed to supply another 1,000 gpm during a 3-hour peak fire demand period.

Potential sources of municipal water supply for the City of West Fargo include the Sheyenne River, Garrison Diversion, West Fargo South Aquifer, and various subregional supply schemes. For any potential surface water supply source, Fargo's existing water treatment plant would be a likely means of treatment.

E. DILWORTH

Water shortages for the City of Dilworth are imminent. Since 1980, annual average water use has been reduced from more than 0.20 mgd to 0.19 mgd. This reduction has been accomplished through rate restructuring and conservation

measures, including sprinkling bans. By the year 2000, however, peak daily shortages may approach 0.22 mgd. The projected year 2030 peak daily shortage is 0.41 mgd.

In 1978, the Insurance Services Office of Minnesota indicated significant flow deficiencies at several locations throughout the city. These deficiencies indicate the need for additional pressure from greater elevated storage, additional high service pumps, and/or improvements from looping water mains (Larson-Peterson, 1983). Loss of pressure in water mains also has the potential to cause back-siphoning from directly connected sources of contamination.

Possible sources of supply include the two Kragnes Aquifer wells for which preliminary hydrologic investigations have already been completed, the City of Moorhead, and the Buffalo Aquifer. The Buffalo Aquifer has very hard water, and development would require a softening and iron removal plant plus a transmission pipeline at least 2 miles long. A tie-in with the Moorhead water supply system or development of the two Kragnes Aquifer wells would involve a much smaller capital investment.

If the city can augment its water supply by 200 gpm using one of the potential sources above, it will still need increased storage capacity to meet maximum daily needs. Preliminary calculations indicate that 0.33 million gallons of additional elevated storage will be required in the year 2000 and 0.35 million gallons by the year 2030. Another methodology used by the Dilworth City Engineer indicates that, with a 200-gpm supply augmentation, 0.43 million gallons of storage will be needed in the year 2005.

F. RURAL COMMUNITIES

Drought-related water supply problems for rural communities commonly stem from inadequate facilities and aging systems. Often underlying these conditions are

insufficient utility revenues or inappropriate management techniques, frequently aggravated by the terms of the original Federal or State financing. In rural water communities, customer charges are often insufficient to cover operating, maintenance, and system replacement costs. Small towns tend to deal with major difficulties as they arise. Water and sewage revenues are not always kept separate from town general accounts, and it is difficult to maintain an adequate cash working balance for the municipal water system or a sinking fund for major maintenance and replacement costs.

The Federal Farmers Home Administration and the State Health Department offer assistance programs for construction of water facilities. However, if terms of the grant provided funding for long-term maintenance and repair, the effectiveness of the facilities might be improved. Federal and State assistance programs should also encourage efficient utility management by predicating awards on local initiative and a history of good management (Howe and others, 1980). The rural community supply deficits and facilities recommended to mitigate the deficits are shown for the years 2000 and 2030 in Tables 49 and 50, respectively. Recommended facilities are similar in type to existing facilities. Communities supplied in bulk by the CRWUA were difficult to evaluate because of a lack of information about the existing facilities. For this reason, design criteria for making supply facility recommendations are shown for only Mapleton and Argusville.

Several considerations favor recommending future supply facilities similar to those existing. First, the municipality is familiar with and already capable of the management and operation of the existing type of facilities. A facility expansion in-kind also allows the municipality to retain local control and

TABLE 49

YEAR 2000 WATER SUPPLY SITUATION - RURAL COMMUNITIES

Community	Peak Daily Shortage (gallons)	Recommended Supply Facilities		
		Well	Storage	Booster Pumps
Sabin	228,000	1 @ 250 gpm	50,000 gallon ground storage	2 @ 350 gpm
Glyndon	43,000	--	98,000 gallon ground storage	2 @ 650 gpm
Riverside	164,100	1 @ 275 gpm	15,000 gallon ground storage	2 @ 100 gpm
Harwood	0	--	--	--
Horace	17,200	--	21,500 gallon ground storage	2 @ 100 gpm
Mapleton	38,000	(1)	--	--
Frontier	0	--	--	--
Argusville	1,000	(2)	--	--
North River	0	--	--	--
Briarwood	670	--	--	--
Reile's Acres (3)	0	--	--	--
Prairie Rose (3)	0	--	--	--
Rustad (3)	--	--	--	--
Kragnes (3)	--	--	--	--

(1) Increase CRWUA allotment from 50,000 gpd to 88,000 gpd at maximum rate of 305 gpm.

(2) Increase CRWUA allotment from 20,000 gpd to 46,000 gpd at maximum rate of 404 gpm.

(3) Individual systems.

TABLE 50

YEAR 2030 WATER SUPPLY SITUATION - RURAL COMMUNITIES

Community	Peak Daily Shortage (gallons)	Recommended Supply Facilities		
		Well	Storage	Booster Pumps
Sabin	330,800	1 @ 250 gpm	90,000 gallon ground storage	2 @ 600 gpm
Glyndon	63,000	--	105,000 gallon ground storage	2 @ 700 gpm
Riverside	164,100	1 @ 275 gpm	15,000 gallon ground storage	2 @ 100 gpm
Harwood	0	--	--	--
Horace	90,200	1 @ 100 gpm	40,000 gallon ground storage	2 @ 250 gpm
Mapleton	124,000	(1)	--	--
Frontier	0	--	--	--
Argusville	26,000	(2)	--	--
North River	0	--	--	--
Briarwood	670	--	--	--
Reile's Acres (3)	0	--	--	--
Prairie Rose (3)	0	--	--	--
Rustad (3)	--	--	--	--
Kragnes (3)	--	--	--	--

(1)Increase CRWUA allotment from 50,000 gpd to 174,000 gpd at maximum rate of 590 gpm.

(2)Increase CRWUA allotment from 20,000 gpd to 46,000 gpd at maximum rate of 203 gpm.

(3)Individual systems.

autonomy in financing the developments. Since the community can phase the new facilities into the existing system at opportune times, the community can take maximal advantage of its initial investments.

VIII. FORMULATION OF WATER SUPPLY ALTERNATIVES

A. GENERAL

In this study, two generations of alternatives were produced. The ultimate goal of all alternatives is to provide a feasible means of meeting future water supply shortages outlined in Chapter VII of this report. The two minimum in-stream flow criteria examined in this report (SRR and Tennant) demonstrate the range of relative cost-effectiveness, environmental impacts, and other effects that different design criteria might produce. These two criteria provide the bases for operational plans developed for the second generation of water supply alternatives; these plans are described later.

B. FIRST GENERATION OF ALTERNATIVES

The first generation of water supply alternatives was formulated specifically for Phase 1, Part 2, of this study. Eleven alternatives representing different combinations of surface water supplies and community demands were developed. These alternatives utilize the SRR criteria, but consider only surface water supplies, not constraints posed by existing facilities. Since approximately 90 percent of the study area communities rely solely on ground water to meet municipal needs, these alternatives present an unrealistic picture of potential water development. Typically, a regional water supply system based on surface-water sources requires extensive pipeline networks and large volumes of reservoir storage. The costs associated with this type of regional system (approximately $40 million) were eventually shown to far exceed the range of costs associated with alternatives utilizing both ground and surface water. Hence, the regional surface water alternatives were dropped from further consideration. However, certain subregional combinations involving Fargo and Moorhead offer potential cost reductions from expanded surface water development. These communities have existing treatment facilities that could be expanded to provide economy-of-scale benefits to water consumers.

C. SECOND GENERATION OF ALTERNATIVES

1. General

The second generation of alternatives was developed in Phase 2. The existing facilities (see Chapter III) were used as a starting point for analysis, and expansions to obtain additional ground-water and surface-water sources were considered. In general, meeting future water needs requires a relatively major subregional scale development to supply the Fargo-Moorhead urban core and localized expansions to supply smaller rural communities. Both the SRR and the Tennant criteria were addressed in these alternatives.

All alternatives address smaller community needs using local expansions that complement existing facilities. Facilities' expansions typically include a new well or additional treated water storage (see Tables 49 and 50 in preceding chapter).

Water supply for the smaller communities was safeguarded in subsequent analysis. Specifically, allowances were made for the smaller communities' demands before determining the supply available to the four major communities that make up the urban core. Generally, the smaller demands have negligible effects on the supply available to the major communities.

Fargo, Moorhead, West Fargo, and Dilworth together account for 97 percent of the study area's total municipal water consumption. Consequently, in Phase 2, water supply alternatives focused on meeting the future needs of these four major communities.

Potential alternatives may utilize increased reservoir storage, wells in aquifers or portions of aquifers presently not developed by the communities, Garrison Diversion flows, extended water pipeline networks, treatment plant expansions, and/or additional treated water storage. A portion of the increased

reservoir storage may come from better utilization of the existing low-head dam on the Red River in Fargo. It is estimated that, with necessary dredging, this dam can maintain 450 acre-feet of usable storage.

Meeting future water supply deficits solely through ground-water sources requires very large well fields and pumping capacities, largely to meet peak requirements. By providing surface-water reservoir storage, ground-water requirements can be drastically reduced. Projected ground-water development is based on first expanding existing well fields, then developing these aquifers to safe yield, and finally moving outward to new aquifers. These discrete breakpoints in ground-water development create natural mixes of ground-water and surface-water sources.

The Maple and South Branch Buffalo Rivers can be ruled out as potential surface-water sources for the Fargo-Moorhead urban core because of long transmission distances and inadequate flows. Possible use of the remaining three rivers can be narrowed down as shown in Table 51. The only logical alternatives, denoted by asterisks in the matrix, utilize the Red and Sheyenne Rivers in the configurations outlined.

Use of these surface water resources was evaluated using both the Tennant and SRR methods of determining minimum in-stream flows. Since the Tennant method allows for larger minimum streamflows, operational plans based on the SRR criteria were devised to minimize the length of time that Red and Sheyenne River flows would be sub-Tennant-standard, thereby reducing the impacts on aquatic resources. When flows decline to the point where withdrawals would reduce streamflows below the 30-percent threshold recommended by Tennant, municipal withdrawals are correspondingly reduced by diverting to ground-water sources until the latter reach 95 percent of the safe yield pumping rate. This is the rate that, if sustained all year, would produce the aquifer's volumetric safe

TABLE 51

MATRIX OF POTENTIAL SURFACE WATER SOURCES

River Source(s) Used	Communities Served: Fargo and West Fargo	Moorhead and Dilworth	Fargo, Moorhead, West Fargo, and Dilworth
Red alone	I	*	I
Sheyenne alone	II	II	II
Buffalo alone	II	II	II
Red and Sheyenne	*	III	**
Red and Buffalo	I	V	I
Sheyenne and Buffalo	II	II	II
Red and Sheyenne and Buffalo	IV	III	IV

Reasons for Elimination

I - Fargo is already using flows from both the Red and Sheyenne Rivers. All feasible surface water alternatives for Fargo must include both sources to meet demands under design drought conditions.

II - Both Fargo and Moorhead currently use flows from the Red River. All feasible surface water alternatives for Fargo and/or Moorhead must include the Red River as a source; other sources cannot meet projected demands without the Red River.

III - The Sheyenne River is located west of Fargo. It is unreasonable to pipe this source to Moorhead unless it is also used by Fargo as part of this alternative.

IV - The Buffalo River provides little or no water in droughts when it is needed most, so the Red-Sheyenne-Buffalo combination is essentially the same as the Red-Sheyenne combination; therefore, it clearly is not cost-effective to add the Buffalo River.

V - The Buffalo River provides little or no water in droughts when it is needed most, so the Red-Buffalo combination is little better than the Red River alone; therefore, it clearly is not cost-effective to add the Buffalo River.

*These are feasible alternatives. Both the Red and Sheyenne Rivers would be used by Fargo and West Fargo; only the Red could be used by Moorhead and Dilworth.

**This is a feasible alternative. Both the Red and Sheyenne Rivers would be used to serve all four communities.

yield. Additional needs are met by drawing once more on river flows until the SRR (7- and 3-cfs) criteria are reached. These additional needs would be divided equally between the two rivers so each has the same percentage of mean annual flow. At that point, available in- or off-stream reservoirs which had been held in reserve are tapped. Peak demands may be met by pumping aquifers at up to double the previous pumping rate for short periods. This would draw on the reserve "banked" by pumping for long periods at rates of 95 percent or less.

The operational plan based on the Tennant criteria would modify the above plan by drawing on reservoir or aquifer storage and not reverting to river withdrawals. This plan would result in somewhat higher streamflows (discussed further in Chapter IX) and, therefore, might be expected to further reduce the impacts on aquatic resources. However, costs are higher because more reservoir storage is needed to protect against the same 50-year design drought.

Using the Tennant criteria, in a typical year, municipal withdrawals would be partially diverted from the Red River to other sources (reservoir or additional aquifers depending on the alternative) for 2 to 4 months. Low-flow analyses of Red and Sheyenne Rivers conducted in Phase 1 of this investigation indicate, however, that in a 50-year drought streamflows would average below 30 percent of the annual means for up to 8 years. In a drought of this severity, brief periods during which flows exceed the 30-percent threshold (such as spring snowmelt runoff) would not be adequate for reservoirs to refill or aquifers to recharge. Therefore, reservoir size or aquifer development must be big enough to furnish up to several years' water supply.

Seven distinct water supply schemes were developed for the Fargo-Moorhead urban core as the second generation of alternatives. A brief synopsis outlining the philosophy of each alternative is shown below. The synopsis qualitatively

considers cost information not expressed until Chapter IX. All these alternatives utilize existing facilities and assume that withdrawals from the West Fargo Aquifer will be reduced to ensure that total withdrawals do not exceed the safe yield. Subregional alternatives consider the North Dakota and Minnesota portions of the urban core as a whole. In separated-subregional alternatives, the urban core is divided in two by State borders.

2. Synopsis of Alternatives

Alternative I is a separated-subregional alternative that uses ground water to meet future shortages. It assumes surface water supplies become completely unavailable; streamflows in the Red and Sheyenne Rivers are below minimum in-stream levels, and no storage is available behind the existing low-head dam. Extensive development of regional aquifers is required, making this an extremely costly alternative.

Alternative II also uses ground water to meet future shortages. This alternative is a subregional alternative that considers the existing low-head storage reservoir. The low-head storage can be used to meet peak demands and permits a less extensive ground-water development than in Alternative I. Costs associated with this alternative were lower than Alternative I, but still significantly higher than the least costly alternatives.

Alternative III is a subregional alternative that features a large off-stream reservoir near the Red River. The reservoir would supplement existing facilities that include the existing low-head dam. Fargo would treat all off-stream reservoir water and distribute it to the other urban core communities. Costs associated with this alternative were significantly higher than the least costly alternatives.

Alternative IV is a separated-subregional alternative that replaces the existing low-head reservoir with a large, new in-stream reservoir. The reservoir would be the sole new source of additional water. Fargo would treat reservoir water for West Fargo, and Moorhead would treat reservoir water for Dilworth. This was one of the two least costly alternatives.

Alternative V is a subregional alternative that uses both increased ground-water development and an off-stream reservoir to meet future water shortages. Fargo's existing water treatment facilities would be expanded to treat additional subregional surface water needs, and Moorhead's facilities would be expanded to treat new subregional ground-water needs. Costs associated with this alternative were significantly higher than the least costly alternatives.

Alternative VI is a subregional alternative similar to Alternative V, but an enlarged in-stream reservoir is used rather than a new off-stream reservoir. The treatment plan is the same as in Alternative V. Alternative VI was one of the two least costly alternatives, and its investment timeline is preferable.

Alternative VII is a separated-subregional alternative that assumes the Minnesota and North Dakota urban core communities would share the existing low-head storage and make additional developments of new sources. North Dakota communities could build an off-stream reservoir or develop new ground-water sources, whereas the Minnesota communities would have to make both types of developments. Costs associated with this alternative were significantly higher than the least costly alternatives.

3. Initial Screening of Alternatives

Any of these alternatives could utilize either the Tennant or the SRR method of maintaining minimum in-stream flows. Both methods of determining streamflows were considered, and, based on an evaluation of the relative advantages and

disadvantages associated with each, the SRR is the primary method selected for facility planning purposes. The major differences resulting from these two methods are the streamflow in the rivers during dry periods and the size and configuration of water supply facilities. Both criteria have identical effects on Red River flows above 200 cfs. For incoming streamflows between 7 and 200 cfs, alternatives utilizing the Tennant criteria will have slightly higher streamflows below the municipal intakes. Below 7 cfs, alternatives based on the SRR criteria yield slightly higher streamflows. A detailed analysis of these effects is presented in Chapter IX.

The urban core communities depend heavily on the surface water of the region (approximately 85 percent), primarily the Red River. Restricting municipal withdrawals as prescribed by the Tennant operating plan requires all available streamflow to be reserved for extended periods during droughts, up to 8 years in a 50-year drought. This would require an alternate source of supply using either ground water or storage. Storage for this length of time, including allowances for sedimentation and evaporation, would require more than 300,000 acre-feet of storage. The Red River cannot furnish this volume within its streambanks, and an off-stream reservoir of this size would be more than 15 square miles in size. Any of the alternatives relying heavily on storage (III, IV, and to a lesser extent V, VI, and VII) are therefore either infeasible or very expensive using this method of determining minimum streamflows. Alternative II, a subregional plan supplementing existing facilities (including existing low-head storage) with additional ground-water supplies, appears to be the most feasible of the alternatives based on the Tennant criteria. It is presented in more detail as Alternative II (Tennant) later in this chapter.

Table 52 provides a brief overview of each alternative under each streamflow operating plan. The information it contains was used to screen the alternatives to those appearing most feasible.

TABLE 52

COMPARISON OF ALTERNATIVES UNDER SRR AND TENNANT CRITERIA

Alternative	Minimum Streamflow Criteria: SRR	Minimum Streamflow Criteria: Tennant
I	Extensive ground-water development on regional scale required. More than three times as costly as the least costly alternatives.	Ground-water sources have capacity to meet demands associated with Tennant criteria. However, river withdrawals would be terminated at an earlier stage than with Alternative I (SRR), necessitating even more ground-water development. More than three times as costly as the least costly alternatives.
II	Extensive ground-water development on regional scale required, though the use of low-head storage reduces associated costs below those of Alternative I (SRR). Less than three times as costly as the least costly alternatives.	The use of low-head storage reduces associated costs below those of Alternative I (Tennant). This is the least costly "Tennant" alternative, but still more than three times as costly as the least costly alternatives.
III	Off-stream reservoir (approximately four times the size of existing low-head storage) and existing low-head storage used to augment existing facilities. Less than three times as costly as the least costly alternatives.	Tennant criteria require municipal withdrawals to be diverted to the off-stream reservoir sooner and longer. This would greatly increase costs over Alternative III (SRR). An order of magnitude more than three times as costly as the least costly alternatives.
IV	Replaces existing low-head storage with a new in-stream reservoir approximately five times as large. One of the two least costly alternatives, but because of the higher pool elevations, it could cause serious environmental impacts along the primary riverbanks. Impacts of this type are unacceptable to Federal and State water resource agencies.	Tennant criteria require an in-stream reservoir much larger than with the SRR criteria. This storage is not available; therefore, this alternative variation is not feasible.

TABLE 52 (Continued)

COMPARISON OF ALTERNATIVES UNDER SRR AND TENNANT CRITERIA

Alternative	Minimum Streamflow Criteria: SRR	Minimum Streamflow Criteria: Tennant
V	Presently utilized aquifers are developed to safe yield. Plus, an off-stream reservoir (approximately twice as large as the existing low-head reservoir) is used to supplement existing low-head storage. Less than three times the cost of the least costly alternatives.	The Tennant criteria require municipal withdrawals to be directed to the off-stream reservoir sooner and longer than with the SRR criteria. This would greatly increase reservoir costs. More than three times the cost of the least costly alternatives.
VI	Presently utilized aquifers developed to safe yield. Plus, a new in-stream reservoir (approximately three times the size of the existing low-head storage) replaces the existing low-head reservoir. Preliminary information indicates that the reservoir pool would stay within the primary banks and would not produce unacceptable environmental impacts. This is one of the least costly alternatives and its investment time-line is preferable.	The Tennant criteria requires an in-stream reservoir much larger than in Alternative VI (SRR) and sufficient storage is not available. This variation of this alternative is not feasible.
VII	Presently utilized aquifers developed to safe yields and an off-stream reservoir (approximately twice the size of the existing low-head reservoir) is constructed to augment existing low-head storage for Minnesota portion of the urban core. For the North Dakota portion, use of the West Fargo Aquifer is curtailed to safe yield, and an off-stream storage reservoir (comparable to existing low-head storage volume) is required to supplement existing low-head storage. Less than three times the cost of the least costly alternatives.	The Tennant criteria require municipal withdrawals to be diverted from the Red River sooner and longer. This would further increase ground-water development and reservoir sizes of Alternative VII (SRR). More than three times as costly as the least costly alternatives.

Alternative I (SRR) is screened from further consideration because of its cost. This alternative requires full development of the Kragnes, Moorhead, Buffalo, and West Fargo South Aquifers, as well as partial development of the Sheyenne Delta Aquifer. It would be an extremely costly alternative. Alternative I (Tennant) is also screened from further consideration. It would be even more expensive than Alternative I (SRR). It includes all the facilities of Alternative I (SRR), plus it requires a larger Sheyenne Delta Aquifer development because termination of river withdrawals would occur at an earlier stage.

Alternative II uses ground water to meet future shortages as does Alternative I, but differs by using existing low-head storage. Storage can be used to meet peak demands and thereby permits less extensive ground-water development. Both Alternative II (SRR) and Alternative II (Tennant) are retained for further evaluation. Alternative II (Tennant) is the least costly of all Tennant-based alternatives.

Alternative III uses an off-stream reservoir to meet future shortages. Alternative III (SRR) is retained for evaluation. The Tennant criteria require river withdrawals to be terminated for much longer periods of time, necessitating a much larger reservoir. The costs for Alternative III (Tennant) would be an order of magnitude above costs for Alternative III (SRR). Alternative III (Tennant) is therefore screened from further consideration.

Alternative IV is similar to Alternative III except that it utilizes an in-stream rather than an off-stream reservoir. Alternative IV (SRR) is one of the two least costly alternatives and has been retained for further evaluation. Its higher pool elevation could cause serious environmental impacts

along the primary riverbanks, however, and may be unacceptable for environmental reasons. These impacts will be discussed in detail in the following chapter. Alternative IV (Tennant) would require a much larger reservoir because river withdrawals would be terminated at an earlier stage. The Red River does not have enough storage, nor would the environmental impacts be acceptable, so this alternative is screened from further consideration.

Alternative V utilizes both additional ground-water development and off-stream storage to meet future shortages. Alternative V (SRR) is retained for further evaluation. Alternative V (Tennant), because it suspends river withdrawals for a much longer time, requires either a larger reservoir or the development of the Sheyenne Delta Aquifer. In either case, it would be much more expensive than Alternative V (SRR); very similar conditions were already evaluated in Alternative II (Tennant) and Alternative III (Tennant). Therefore, Alternative V (Tennant) is screened from further evaluation.

Alternative VI is much like Alternative V except an in-stream rather than an off-stream reservoir is utilized. Alternative VI (SRR) is one of the two least costly alternatives and is retained for further consideration. As with the Tennant version of the previous alternative, Alternative VI (Tennant) is screened from further consideration. It would require either a very large in-stream reservoir of the type already considered and dismissed in Alternative IV (Tennant), or it would require development of the Sheyenne Delta Aquifer. A development of the latter type is already addressed in retained Alternative II (Tennant).

Alternative VII assumes the Minnesota and North Dakota urban core communities share the existing low-head storage and separately develop additional sources to meet their own needs. Alternative VII (SRR) requires the Minnesota side to

fully develop the Kragnes, Moorhead, and Buffalo Aquifers and construct an off-stream reservoir approximately twice the size of the existing in-stream reservoir. The North Dakota side would need an off-stream reservoir comparable in size to the existing in-stream reservoir. This alternative is retained for further evaluation. Alternative VII (Tennant) would require municipal withdrawals to be diverted from the rivers sooner and longer. This would increase the off-stream reservoir costs to many times those of the least costly alternatives and to a level much higher than the cost of Alternative II (Tennant), the least-cost Tennant-based alternative, Therefore, Alternative VII (Tennant) is dropped from further consideration.

The remainder of this chapter provides a detailed discussion of the alternatives which have been retained.

4. Discussion of Retained Alternatives

In Alternative II (SRR), the four urban core communities are coordinated into a subregional system whereby they share all new water supplies. These communities continue to use their existing facilities and sources of supply, though new supplies are utilized in a more cost-effective manner. Sources of new supplies include ground water and storage behind the existing low-head dam.

The subregional organization prevents the development of redundant systems and generates other efficiencies. Under this plan, Fargo would expand its treatment plant primarily to accommodate the new surface water needs of the urban core communities, and Moorhead would expand its facilities primarily to treat the additional ground-water needs during drought. Thus, West Fargo and Dilworth would not have to build their own treatment plants and the most economical mix of surface and ground water could be utilized at all times.

This alternative assumes use of the existing low-head storage. The low-head dam on the Red River has potential to provide a total of approximately 600 acre-feet of storage. It is estimated that, with necessary dredging, this dam can maintain 450 acre-feet of usable storage considering sedimentation and evaporation. Alternative II (SRR) also assumes full development of the Moorhead, Kragnes, and Buffalo Aquifers. Full development means that there are facilities capable of delivering the full safe yield of the aquifer in the manner required by the operating plan. The West Fargo South Aquifer is partially developed for an additional 0.24 bgy (approximately 6 mgd).

Alternative II (SRR) utilizes the SRR operating plan. Ground-water sources and surface-water sources would be used in any manner until municipal withdrawals cause streamflows to fall to 30 percent of mean annual flows. Then, the "excess" municipal demands are diverted to ground-water sources until these withdrawals reach 95 percent of safe yield rates.

At this point, streamflows could be drawn down to a minimum of 7 cfs in the Red River and 3 cfs in the Sheyenne River to meet additional needs. These additional needs would be divided equally between the two rivers so each has the same percentage of mean annual flow. Withdrawals from the reservoir would occur only after minimum in-stream flows had been reached.

Alternative II (Tennant) is essentially Alternative II (SRR) with modifications required to employ the Tennant operating plan. It retains the same subregional organization. All the sources utilized in Alternatives II (SRR) are fully developed in this alternative. In addition, another 8.58 bgy is obtained by partially developing the Sheyenne Delta Aquifer.

Drawing 1 displays the facilities of Alternative II (Tennant). This alternative employs the same facility expansions as outlined in Alternative II (SRR). However, due to the additional volume of ground water from the West Fargo South

and the Sheyenne Delta Aquifers, Fargo must now treat significant portions of the ground water during periods of drought.

Alternative II (Tennant) meets the supply deficits of the smaller communities with the recommended municipal supply facilities outlined in Chapter VII. Drawing 1 also displays these facilities.

The Tennant operating plan allows for somewhat higher streamflows (see Chapter IX). When flows decline to the point where municipal withdrawals would reduce streamflows below Tennant's 30-percent threshold, the "excess" municipal demands are diverted to the Kragnes, Moorhead, Buffalo, West Fargo South, and Sheyenne Delta Aquifers. When these aquifers are producing at 95 percent of their safe yield rates, additional peak demands can be met by increased pumping of storage (either reserved in these aquifers or behind the existing low-head dam). Municipal demands would partially or totally revert back to the Sheyenne or Red Rivers whenever the streamflows once again exceeded 30 percent threshold.

Alternative III (SRR) utilizes an off-stream reservoir near the Red River and storage behind the existing low-head dam to meet future shortages. This is a subregional alternative; Fargo's treatment facilities would be expanded to treat off-stream reservoir water and distribute it to the remaining urban core communities via intercommunity connections. The Moorhead facilities would be expanded to meet Dilworth's additional needs. In this way, existing facilities would be optimized, and only Fargo and Moorehad treatment facilities would require substantial expansion. These facilities, as well as those required for the rural communities, are shown in Drawing 2.

Initially, consideration was given to possible reservoirs on the Red, Sheyenne, and Buffalo Rivers. The Buffalo, however, is projected to have zero flow for periods of several weeks during a 50-year drought, and its flow contribution at most other times is relatively minor. Thus, the focus was narrowed to the Red and Sheyenne Rivers. These two rivers currently supply a major portion of water used by Fargo and Moorhead.

Two off-stream storage scenarios are feasible, one serving the Fargo-West Fargo and Moorhead-Dilworth areas separately, and the other a subregional plan serving all four communities from a single reservoir. In the first scenario, the Moorhead-Dilworth area would be served by a reservoir near the Red River and the Fargo-West Fargo area would be served by a reservoir near either the Red or Sheyenne River. The second scenario provides a single reservoir near the Red River that would serve all four communities. The latter alternative would be more efficient and economical. Thus, analysis of possible off-stream reservoirs leads to the preferred alternative of one reservoir near the Red River.

The reservoir is assumed to be located south of Fargo on the North Dakota side of the Red River (see Drawing 2). Several potential sites appear to exist in the southern half of Barnes Township. For this evaluation, a site in the west half of Section 25 was selected. Other sites could be chosen, with the principal difference being the length of pipe required from the river and to the treatment plant.

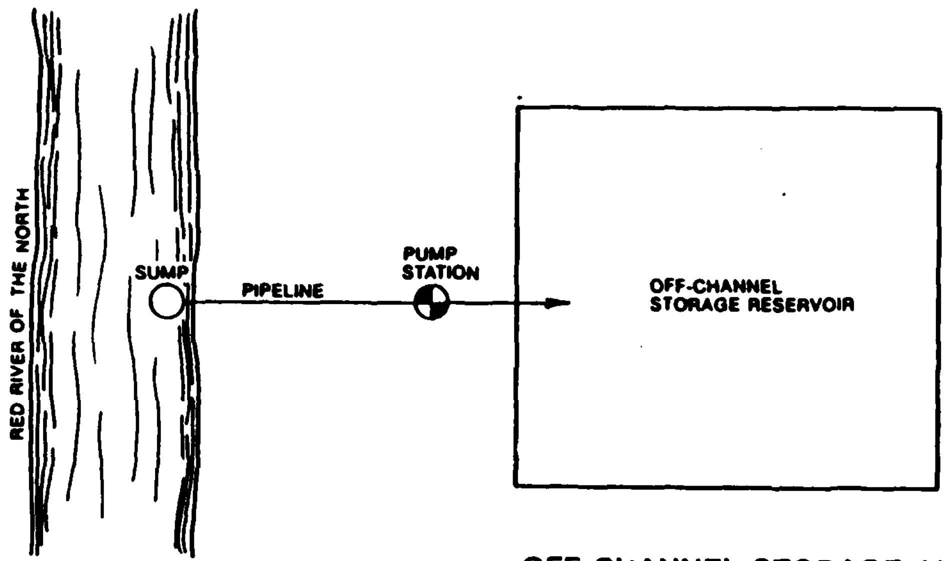
The reservoir would hold approximately 1,700 acre-feet of usable storage. This, along with an estimated 450 acre-feet behind the existing dam, would provide total usable storage of 2,150 acre-feet (more than 700 million gallons). A single-purpose water supply reservoir would be constructed as shown in

Figure 13 with 3:1 side slopes, 3 feet of freeboard, and 5 feet reserved for sedimentation. A reservoir of this size would require approximately 150 acres of land. The area would need to be enclosed by chain-link security fences. The reservoir could be designed for multiple purposes to include recreation. A discussion of how recreational use might alter reservoir design is provided later.

Rather than pumping the raw water to several treatment plants, it is assumed that the Fargo plant would treat all flows from the reservoir. Connections would tie the existing Fargo system to the existing systems of West Fargo, Moorhead, and Dilworth. These facilities are also shown in Drawing 2. All connections would be sized to satisfy peak requirements in excess of existing supply capacities.

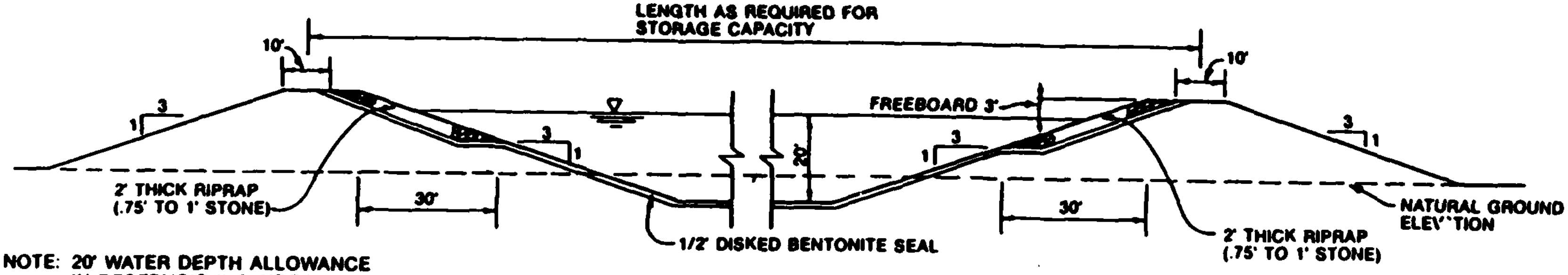
This alternative assumes that when flows in the river are not sufficient to meet total demands, Fargo and Moorhead would draw from the Red River at rates proportional to their population. Pumps to the treatment plants are sized to meet the peak daily deficit with the largest pump out of service. In the year 2030, the peak daily deficit for Fargo, West Fargo, Moorhead, and Dilworth has been projected to be 30.24 mgd. It is assumed that the existing Fargo treatment plant will be expanded to meet these demands.

The proposed reservoir would be maintained full at all times except during use, which would only be when other sources of supply are not sufficient to meet demands. In laying out the alternative and sizing it, certain assumptions were made about the use of other sources. Before drawing from the reservoir, it is assumed that all available water from the Red River and Sheyenne River and all existing well fields would be used in accordance with the SRR operating plan



NOTE: PUMP STATION WILL DRAW FROM RIVER AND FEED TO OFF-CHANNEL STORAGE RESERVOIR, OR DRAW FROM OFF-CHANNEL STORAGE

OFF-CHANNEL STORAGE AND TRANSMISSION



NOTE: 20' WATER DEPTH ALLOWANCE IN RESERVOIR INCLUDES A 5' ALLOWANCE FOR SEDIMENTATION

TYPICAL OFF-CHANNEL STORAGE RESERVOIR CROSS-SECTION

FARGO-MOORHEAD URBAN WATER SUPPLY/CONSERVATION INVESTIGATION

TYPICAL OFF-STREAM RESERVOIR

E.A. HICKOK & ASSOCIATES
HYDROLOGISTS-ENGINEERS
MINNEAPOLIS-MINNESOTA

fig. 13

described below. Sheyenne River water would be delivered via the direct diversion to the Fargo treatment plant; the Red River water would be made available by pipelines from the Fargo and Moorhead intake structures.

Under normal operations, the rivers and ground-water sources would be used to meet demands until either streamflows below the municipal intakes decline to 30 percent of mean annual flow or ground-water withdrawals reach 95 percent of the safe yield rate. Once either threshold is reached, additional demand will be satisfied by drawing on the other source until its threshold is also reached. This operating plan would help maintain aquatic resources because it uses ground water prior to withdrawing surface water below 30 percent of the mean annual flow. This would shorten the time that river flows would be below the 30-percent threshold recommended by Tennant.

According to the SRR operating plan, when streamflows below the municipal intakes fall to 30 percent of mean annual flow and ground-water withdrawals reach 95 percent of the safe yield rate, additional demands would be satisfied by drawing on river flows. These additional needs would be divided equally between the two rivers so each has the same percentage of mean annual flow. In no case, however, would flows be drawn below 7 cfs in the Red River or 3 cfs in the Sheyenne. When these minimum in-stream flows are reached, withdrawals from the reservoir would begin. Peak demands can also be satisfied by pumping aquifers at up to double their safe yield rates for short periods of time without any long-term depletion of the supply. After each critical period, pumping rates would return to no more than 95 percent of the safe yield rate.

The reservoir is sized to span a 50-year drought under the SRR operating plan outlined above. Actual operation may vary from this scenario. For instance, reservoir storage may actually be drawn upon before minimum in-stream flows are

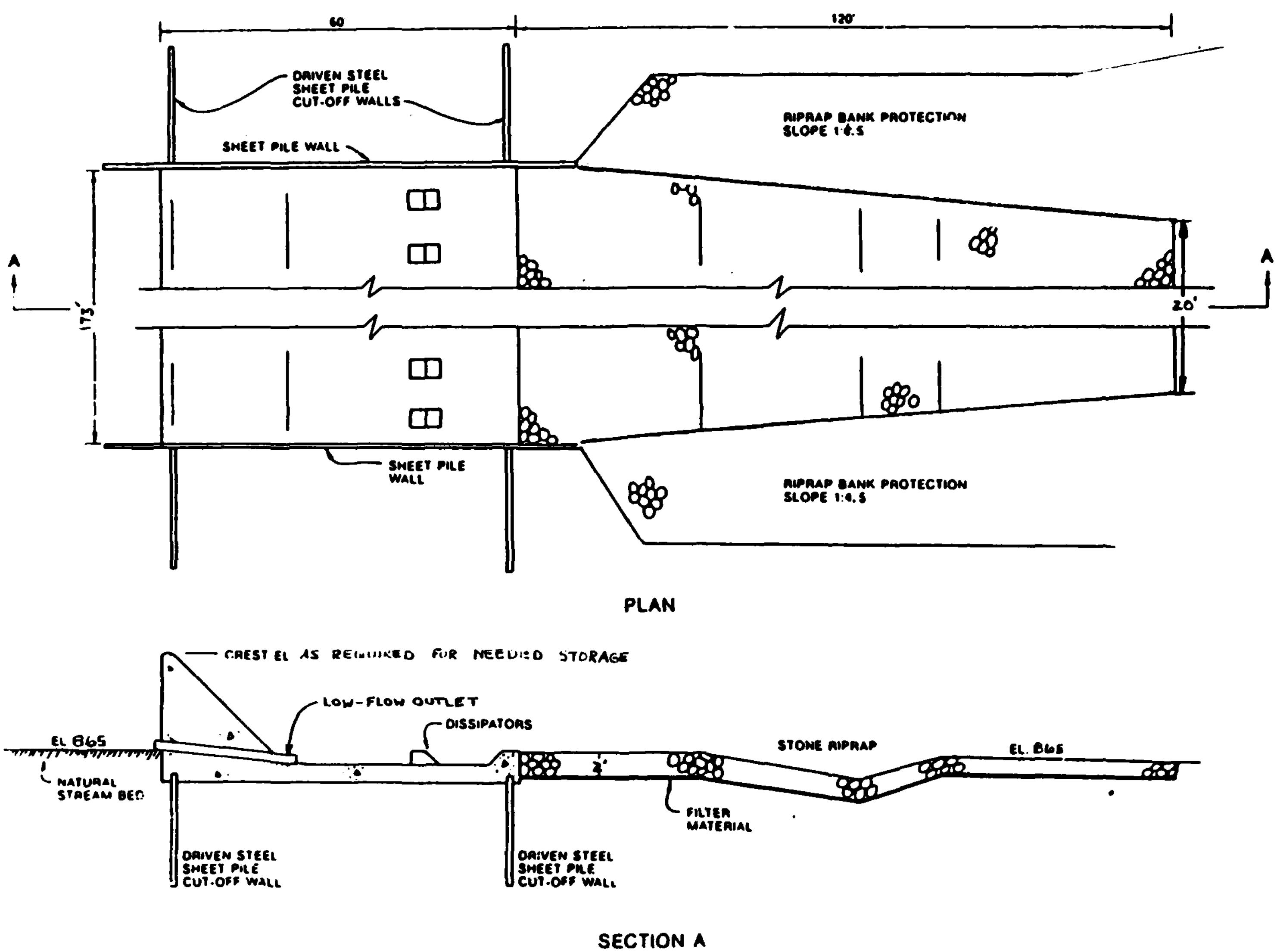
reached, as prescribed in the Tennant operating plan. This method of operation would not satisfy peak demands during a 50-year drought with the reservoir sizes suggested in this alternative.

Alternative IV (SRR) uses in-stream surface-water storage to meet the future water supply deficits projected for study area communities. An enlarged in-stream reservoir is shared by the North Dakota and Minnesota portions of the urban core. Fargo treatment facilities also serve West Fargo, and Moorhead treatment facilities also serve Dilworth. The key component is a low-head dam on the Red River at Fargo (see Drawing 3). The structure is designed to provide a reservoir large enough to supply the additional peak water needs of West Fargo, Fargo, Moorhead, and Dilworth, as well as non-municipal needs, during a drought with a 50-year recurrence interval. A mass curve analysis was used to determine the size of the reservoir, as described in the previous chapter.

A pool elevation was then determined based on generalized cross-sectional information and a corresponding structure designed. Exact specifications would be determined from detailed field surveys.

The proposed dam would be on the Red River near Fargo's St. Johns Hospital at the juncture of the river and 5th Avenue South. It may also be possible to upgrade the existing structure at this location.

The proposed structure is a concrete low-head dam with a fixed crest and a low-flow outlet capable of delivering 7 cfs during low-flow periods. A typical low-head dam design is shown in Figure 14. The detailed design of the structure would consider other factors, such as public safety, fisheries requirements, and aesthetics.



Low-Head Dam

FARGO-MOORHEAD URBAN WATER SUPPLY/CONSERVATION INVESTIGATION	E.A. HICKOK & ASSOCIATES HYDROLOGISTS-ENGINEERS MINNEAPOLIS-MINNESOTA	fig. 14
TYPICAL LOW-HEAD DAM		

The crest would be at approximately elevation 883, a level higher than the primary stream banks. The normal pool would extend outside the primary banks in some portions and would influence water surface elevations up to 35 miles upstream. It would have a total volume of approximately 3,000 acre-feet, including approximately 850 acre-feet to allow for sedimentation and evaporation. Therefore, the usable storage would be approximately 2,150 acre-feet.

Water for West Fargo would be obtained from expanded Fargo treatment facilities. Water for Dilworth would be treated by Moorhead's facilities. The raw water stored in the reservoir pool would be available to Fargo and Moorhead treatment plants via their existing surface water intake systems. The intake, transmission, and treatment facilities for both communities may have to be enlarged to handle the increased flows. This alternative would utilize the SRR operating plan as described in Alternative III (SRR).

Alternative V (SRR) is a subregional alternative that uses both increased ground-water development and an off-stream reservoir to meet future water deficits. Fargo's existing water treatment facilities would be expanded to treat additional subregional surface water needs. During drought, Fargo would treat the off-stream reservoir water that the urban core required. Moorhead's facilities would be expanded to treat new subregional ground-water needs. During a drought, Moorhead would treat water from the Kragnes, Moorhead, and Buffalo Aquifers for the urban core. The Red River in-stream storage could be treated by either plant using existing supply facilities.

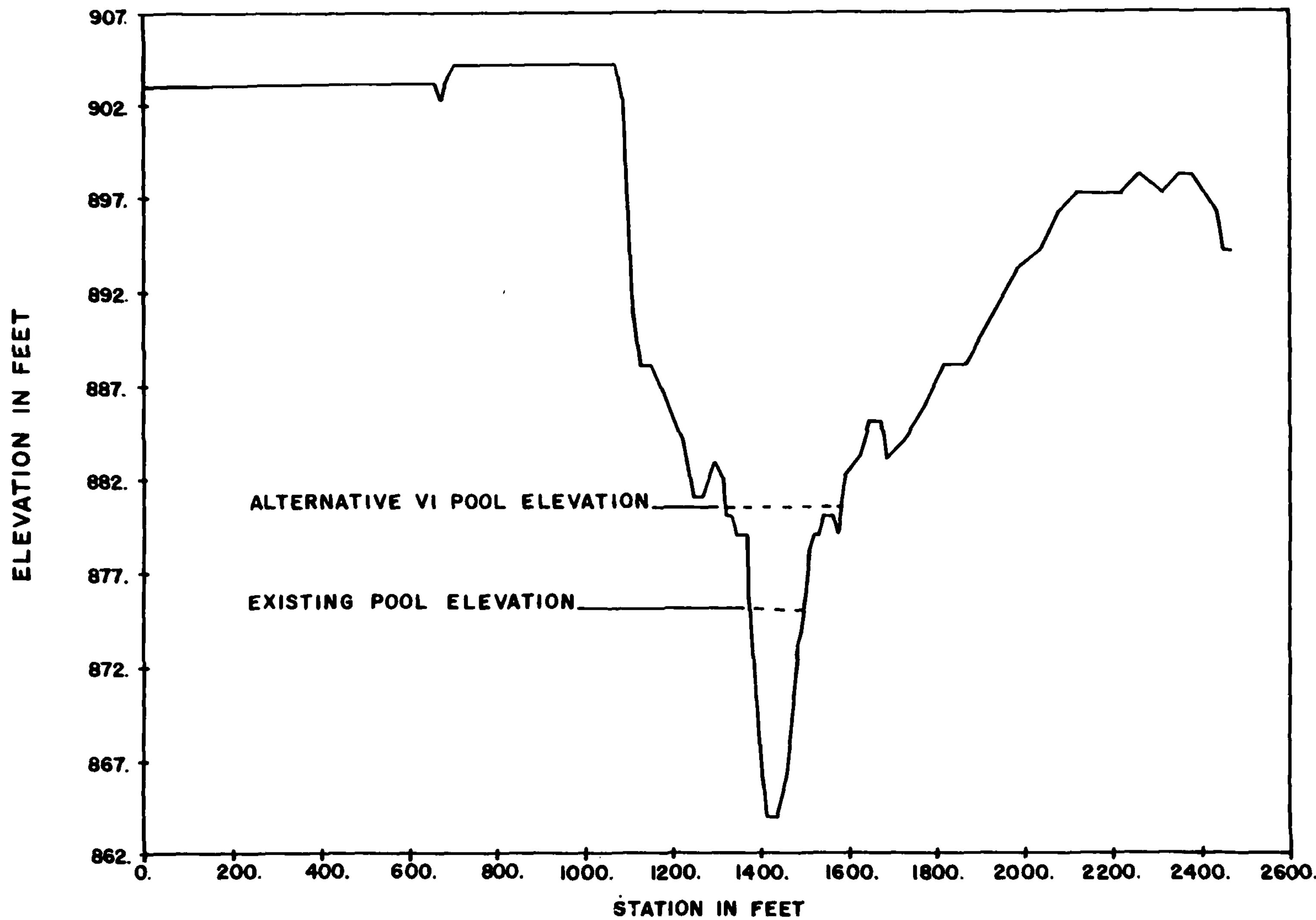
The new off-stream reservoir would be located south of Fargo and constructed as specified in Alternative III (SRR). The reservoir would hold approximately 800 acre-feet of usable storage and would cover approximately 76 acres. Combined with the 450 acre-feet of storage behind the existing low-head dam,

a total of 1,250 acre-feet of surface-water storage are provided. The layout of transmission facilities associated with the off-stream reservoir would be like that shown for Alternative III (SRR) in Drawing 2. The layout of ground-water facilities would be identical to that of Alternative VI (see Drawing 4). The SRR operating plan would be used for this alternative as described in Alternative III (SRR).

Alternative VI (SRR) is a subregional alternative that uses new ground-water development and an enlarged in-stream reservoir to meet additional future needs. The existing subregional supply facilities are expanded so that Fargo could treat new surface-water needs for the urban core and Moorhead could treat new ground-water needs. The water facilities associated with this alternative are shown in Drawing 4.

New ground water would be supplied by fully developing the Kragnes, Moorhead, and Buffalo Aquifers. New surface-water needs would be met by replacing the existing low-head dam with a new dam designed in the same manner as previously discussed (see Alternative IV (SRR)). The dam crest would be at approximately elevation 880, 5 feet higher than the existing dam's crest. The reservoir pool would have a usable storage of approximately 1,250 acre-feet and a total storage of 1,900 acre-feet. The total storage includes 650 acre-feet for sedimentation and evaporation. Preliminary cross-sectional information indicates that this pool would be within the primary banks of the river with a freeboard of up to 5 feet (see Figure 15). This information also implies that the reservoir pool could influence water surface elevations up to 30 miles upstream.

The existing surface water intakes for Fargo and Moorhead would be retained and expanded. Fargo's intake facilities would be designed to handle the new subregional demands from the reservoir. Moorhead's expansion may be designed to optimize the mix of the city's surface and ground-water sources under peak



FARGO-MOORHEAD URBAN WATER SUPPLY/CONSERVATION INVESTIGATIONS	E.A. HICKOK & ASSOCIATES HYDROLOGISTS-ENGINEERS MINNEAPOLIS-MINNESOTA	fig. 15
TYPICAL CROSS SECTION OF RED RIVER AT FARGO		

demand conditions. Inter-community connections are shown in Drawing 4. These connections are sized to satisfy peak requirements in excess of existing supply capacities. This alternative would utilize the SRR operating plan as described in Alternative III (SRR).

Alternative VII (SRR) has a separated-subregional organization representing "without project" conditions. This alternative considers that expansions or other improvements are made by individual communities on an as-needed basis (see Chapter VII). It assumes that Fargo-West Fargo and Moorhead-Dilworth would develop sources independently and to the exclusion of each other. Both pairs of communities would share the storage behind the existing low-head dam. Other sources of new water would include off-stream reservoirs or additional ground-water development. The water facilities for this alternative are shown in Drawing 5.

Some assumptions were made in order to evaluate Fargo-West Fargo and Moorhead-Dilworth for separate facilities. Available Red River flows and existing low-head storage would be allocated to Fargo-West Fargo and Moorhead-Dilworth on a 70:30 basis, proportional to their respective populations. Therefore, all Sheyenne River diversions and 70 percent of the Red River flows and reservoir storage would be credited to Fargo-West Fargo. Without the Sheyenne diversion channel, Red River flows would fall below minimum in-stream requirements in the 50-year design drought. This leaves Moorhead-Dilworth with essentially no surface-water sources other than a 30-percent share of the existing in-stream reservoir. These communities will be unable to meet year 2030 demands even after full development of the Kragnes, Moorhead, and Buffalo Aquifers. Therefore, the only options open to Moorhead-Dilworth in Alternative VII (SRR) are construction of an off-stream reservoir or a large low-head dam. Construction of a low-head dam to meet needs is essentially the same as evaluated in Alternative VI (SRR) (without the connecting pipe); thus, only the off-stream reservoir is considered here. Since

actual streamflow data for the Red River without the Sheyenne diversion are not available, sizing of additional facilities is based on streamflow estimates.

The estimated shortage for Moorhead-Dilworth, considering the full aquifer development mentioned above, is 0.24 bgy. This need can be met with a 750 acre-foot storage reservoir near the Red River. This reservoir would occupy approximately 72 acres south of Moorhead. The Fargo-West Fargo deficits are estimated to be 0.13 bgy. These needs can be satisfied by constructing a 400 acre-foot off-stream reservoir south of Fargo.

Drawing 5 displays the facilities required for these subregional developments. This alternative would utilize the SRR operating plan as described in Alternative III (SRR).

5. Summary of Water Supply Alternatives

Tables 53 and 54 summarize the additional water sources in years 2000 and 2030 for the retained alternatives. The tables also display the impacts of the Garrison Diversion on the alternatives (Alternatives II (SRR)-G, etc.). As discussed in Chapter IV, full implementation of the Garrison Diversion is possible in future decades though it is strongly opposed by the Canadian government and environmentalists at the present time. Full implementation would increase 7-day, 50-year low streamflows in the study area by an estimated 2.39 mgd (3.7 cfs) in the Sheyenne River and 0.58 mgd (0.89 cfs) in the Red River. This would reduce the demands on new sources accordingly.

A variation of the Garrison Diversion was also briefly considered and rejected. This variation would divert flows from the James River to both the Fargo-Moorhead and Grand Forks-East Grand Forks areas. This diversion would require approximately 180 miles of large diameter pipeline. Both areas have been shown to possess adequate water supplies much closer to their demand centers, making this variaton unnecessary and comparatively too costly.

Table 55 summarizes the ground-water withdrawals from aquifers developed for the retained alternatives in year 2030. The relationship between existing and additional ground-water withdrawals is also shown.

TABLE 53

SUMMARY OF URBAN CORE WATER SUPPLY ALTERNATIVES
YEAR 2030

Alternative	Additional Water Supply Sources: Fargo and West Fargo / Moorhead and Dilworth
II (SRR)	Kragnes Aquifer - 0.01 bgy
	Moorhead Aquifer - 0.32 bgy
	Buffalo Aquifer - 0.98 bgy
	West Fargo South Aquifer - 0.24 bgy
	(also use existing low-head dam storage - 450 ac-ft)
II (Tennant)	Kragnes Aquifer - 0.01 bgy
	Moorhead Aquifer - 0.32 bgy
	Buffalo Aquifer - 0.98 bgy
	West Fargo South Aquifer - 0.37 bgy
	Sheyenne Aquifer - 8.58 bgy
	(also use existing low-head dam storage - 450 ac-ft)
III (SRR)	Off-Stream Reservoir near Red River - 1,700 ac-ft
	(also use existing low-head dam storage - 450 ac-ft)
IV (SRR)	Reservoir in Red River - 2,150 ac-ft (+ 850 ac-ft for sedimentation and evaporation)
	(replaces existing low-head dam storage)
V (SRR)	Kragnes Aquifer - 0.01 bgy
	Moorhead Aquifer - 0.32 bgy
	Buffalo Aquifer - 0.98 bgy
	Off-Stream Reservoir near Red River - 800 ac-ft
	(also use existing low-head dam storage - 450 ac-ft)
VI (SRR)	Kragnes Aquifer - 0.01 bgy
	Moorhead Aquifer - 0.32 bgy
	Buffalo Aquifer - 0.98 bgy
	Reservoir in Red River - 1,250 ac-ft (+ 650 ac-ft for sedimentation and evaporation)
	(replaces existing low-head dam storage)

TABLE 53 (continued)

SUMMARY OF URBAN CORE WATER SUPPLY ALTERNATIVES
YEAR 2030

Alternative	Additional Water Supply Sources: Fargo and West Fargo	Additional Water Supply Sources: Moorhead and Dilworth
VII (SRR)	Off-Stream Reservoir near Red River - 400 ac-ft	Kragnes Aquifer - 0.01 bgy Moorhead Aquifer - 0.32 bgy Buffalo Aquifer - 0.98 bgy Off-Stream Reservoir near Red River - 750 ac-ft
	(also use existing low-head dam storage - 450 ac-ft)	
II (SRR)-G	Kragnes Aquifer - 0.01 bgy Moorhead Aquifer - 0.32 bgy Buffalo Aquifer - 0.98 bgy West Fargo South Aquifer - 0.06 bgy (also use existing low-head dam storage - 450 ac-ft)	
III (SRR)-G	Off-Stream Reservoir near Red River - 1,000 ac-ft (also use existing low-head dam storage - 450 ac-ft)	
IV (SRR)-G	Reservoir in Red River - 1,450 ac-ft (+ 650 ac-ft for sedimentation and evaporation) (replaces existing low-head dam storage)	
V (SRR)-G	Kragnes Aquifer - 0.01 bgy Moorhead Aquifer - 0.32 bgy Buffalo Aquifer - 0.98 bgy Off-Stream Reservoir near Red River - 200 ac-ft (also use existing low-head dam storage - 450 ac-ft)	
VI (SRR)-G	Kragnes Aquifer - 0.01 bgy Moorhead Aquifer - 0.32 bgy Buffalo Aquifer - 0.98 bgy Reservoir in Red River - 650 ac-ft (+ 550 ac-ft for sedimentation and evaporation) (replaces existing low-head dam storage)	
VII (SRR)-G	Off-Stream Reservoir near Red River - 225 ac-ft	Moorhead Aquifer - 0.32 bgy Buffalo Aquifer - 0.98 bgy Off-Stream Reservoir near Red River - 750 ac-ft
	(also use existing low-head dam storage - 4[illegible] ac-ft)	

TABLE 54

SUMMARY OF URBAN CORE WATER SUPPLY ALTERNATIVES
YEAR 2000

<table>
<tr><th rowspan="2">Alternative</th><th colspan="2">Additional Water Supply Sources</th></tr>
<tr><th>Fargo and West Fargo</th><th>Moorhead and Dilworth</th></tr>
<tr><td>II (SRR)</td><td colspan="2">Kragnes Aquifer - 0.01 bgy
Moorhead Aquifer - 0.32 bgy
Buffalo Aquifer - 0.73 bgy
(also use existing low-head dam storage - 450 ac-ft)</td></tr>
<tr><td>III (SRR)</td><td colspan="2">Off-Stream Reservoir near Red River - 200 ac-ft
(also use existing low-head dam storage - 450 ac-ft)</td></tr>
<tr><td>IV (SRR)</td><td colspan="2">Reservoir in Red River - 650 ac-ft (+ 450 ac-ft for sedimentation and evaporation)
(replaces existing low-head dam storage)</td></tr>
<tr><td>V (SRR)</td><td colspan="2">Kragnes Aquifer - 0.01 bgy
Moorhead Aquifer - 0.32 bgy
Buffalo Aquifer - 0.73 bgy
(also use existing low-head dam storage - 450 ac-ft)</td></tr>
<tr><td>VI (SRR)</td><td colspan="2">Kragnes Aquifer - 0.01 bgy
Moorhead Aquifer - 0.32 bgy
Buffalo Aquifer - 0.73 bgy
(also use existing low-head dam storage - 450 ac-ft)</td></tr>
<tr><td rowspan="2">VII (SRR)</td><td>Additional Water Supply Sources Not Required</td><td>Kragnes Aquifer - 0.01 bgy
Moorhead Aquifer - 0.32 bgy
Buffalo Aquifer - 0.98 bgy
Off-Stream Reservoir near Red River - 350 ac-ft</td></tr>
<tr><td colspan="2">(with use of existing low-head dam storage - 450 ac-ft)</td></tr>
<tr><td>II (SRR)-G</td><td colspan="2">Additional Water Supply Source Not Required
(with use of existing low-head dam storage - 450 ac-ft)</td></tr>
</table>

TABLE 54 (continued)

SUMMARY OF URBAN CORE WATER SUPPLY ALTERNATIVES
YEAR 2000

Alternative	Additional Water Supply Sources: Fargo and West Fargo	Additional Water Supply Sources: Moorhead and Dilworth
III (SRR)-G	Additional Water Supply Sources Not Required (with use of existing low-head dam storage - 450 ac-ft)	
IV (SRR)-G	Reservoir in Red River - 650 ac-ft (+ 450 ac-ft for sedimentation and evaporation) (replaces existing low-head dam storage)	
V (SRR)-G	Additional Water Supply Sources Not Required (with use of existing low-head dam storage - 450 ac-ft)	
VI (SRR)-G	Additional Water Supply Sources Not Required (with use of existing low-head dam storage - 450 ac-ft)	
VII (SRR)-G	Additional Water Supply Sources Not Required	Kragnes Aquifer - 0.01 bgy Moorhead Aquifer - 0.32 bgy Buffalo Aquifer - 0.98 bgy Off-Stream Reservoir near Red River - 350 ac-ft
	(with use of existing low-head dam storage - 450 ac-ft)	

TABLE 55

ADDITIONAL GROUND-WATER WITHDRAWALS
FOR YEAR 2030 TOGETHER WITH EXISTING WITHDRAWALS (bgy)
FARGO, MOORHEAD, WEST FARGO, AND DILWORTH

	Buffalo Aquifer			West Fargo Aquifer			West Fargo So. Aquifer		
	Exist.	Added	Total	Exist.	Added	Total	Exist.	Added	Total
II (SRR)	0.48	0.98	1.46	0.55	-0.11	0.44	0.07	0.24	0.31
II (Tennant)	0.48	0.98	1.46	0.55	-0.11	0.44	0.07	0.37	0.44
III (SRR)	0.48	0	0.48	0.55	-0.11	0.44	0.07	0	0.07
IV (SRR)	0.48	0	0.48	0.55	-0.11	0.44	0.07	0	0.07
V (SRR)	0.48	0.98	1.46	0.55	-0.11	0.44	0.07	0	0.07
VI (SRR)	0.48	0.98	1.46	0.55	-0.11	0.44	0.07	0	0.07
VII (SRR)	0.48	0.98	0.48	0.55	-0.11	0.44	0.07	0	0.07
II (SRR)-G	0.48	0.98	1.46	0.55	-0.11	0.44	0.07	0.06	0.13
III (SRR)-G	0.48	0	0.48	0.55	-0.11	0.44	0.07	0	0.07
IV (SRR)-G	0.48	0	1.46	0.55	-0.11	0.44	0.07	0	0.07
V (SRR)-G	0.48	0.98	1.46	0.55	-0.11	0.44	0.07	0	0.07
VI (SRR)-G	0.48	0.98	1.46	0.55	-0.11	0.44	0.07	0	0.07
VII (SRR)-G	0.48	0.98	1.46	0.55	-0.11	0.44	0.07	0	0.07

TABLE 55 (continued)

ADDITIONAL GROUND-WATER WITHDRAWALS
FOR YEAR 2030 TOGETHER WITH EXISTING WITHDRAWALS (bgy)
FARGO, MOOREHEAD, WEST FARGO, AND DILWORTH

	Moorhead Aquifer			Kragnes Aquifer			Sheyenne Delta Aquifer		
	Exist.	Added	Total	Exist.	Added	Total	Exist.	Added	Total
II (SRR)	0.12	0.32	0.44	0.08	0.01	0.09	0.9	0	0.9
II (Tennant)	0.12	0.32	0.44	0.08	0.01	0.09	0.9	8.6	9.5
III (SRR)	0.12	0	0.12	0.08	0	0.08	0.9	0	0.9
IV (SRR)	0.12	0	0.12	0.08	0	0.08	0.9	0	0.9
V (SRR)	0.12	0.32	0.44	0.08	0.01	0.09	0.9	0	0.9
VI (SRR)	0.12	0.32	0.44	0.08	0.01	0.09	0.9	0	0.9
VII (SRR)	0.12	0.32	0.44	0.08	0.01	0.09	0.9	0	0.9
II (SRR)-G	0.12	0.32	0.44	0.08	0.01	0.09	0.9	0	0.9
III (SRR)-G	0.12	0	0.12	0.08	0	0.08	0.9	0	0.9
IV (SRR)-G	0.12	0	0.12	0.08	0	0.08	0.9	0	0.9
V (SRR)-G	0.12	0.32	0.44	0.08	0.01	0.09	0.9	0	0.9
VI (SRR)-G	0.12	0.32	0.44	0.08	0.01	0.09	0.9	0	0.9
VII (SRR)-G	0.12	0.32	0.44	0.08	0.01	0.09	0.9	0	0.9

IX. ASSESSMENT OF ALTERNATIVES

A. ECONOMIC IMPACTS

In the water-supply alternatives developed in the preceding section, facilities such as number and size of wells, size of reservoirs, and pumping requirements differ from alternative to alternative. However, small community improvements and the need for expanded treatment facilities at Fargo and Moorhead remain unchanged regardless of the alternative selected. Therefore, for comparative purposes, the costs outlined in this section reflect only items with costs that vary from alternative to alternative.

Cost estimates have been developed, as summarized in Table 56, that compare each of the alternatives. The data in Table 56 present the alternative-dependent capital costs, including wells, pumps, piping, low-head dams, off-stream reservoirs, and system interconnections. All costs in this screening evaluation are capital costs in 1984 dollars, but do not reflect timing of the expenditures.

Alternative II (SRR) meets additional demands with storage behind the existing low-head dam and increased development of the Kragnes, Moorhead, Buffalo, and West Fargo South Aquifers (see Chapter VIII). The estimated costs for these facilities are $3,666,000 to meet year 2000 demands and $11,175,000 to meet year 2030 demands. Somewhat greater streamflows are available with the Garrison Diversion so costs are slightly reduced. The costs associated with the Garrison Diversion variant (Alternative II (SRR)-G) are $1,047,000 for year 2000 demands and $7,266,000 for year 2030 demands.

Alternative II (Tennant) is based on minimum in-stream flow requirements determined by the Tennant Method. Average flows would be below the Tennant threshold for periods of up to 8 years under 50-year drought conditions. During

TABLE 56

COMPARISON OF ALTERNATIVE-DEPENDENT COSTS

Alternative	Year 2000	Year 2030
II (SRR)	\$ 3,666,000	\$11,175,000
II (Tennant)	--	\$31,875,000
III (SRR)	\$ 5,837,000	\$11,926,000
IV (SRR)	\$ 3,385,000	\$ 5,235,000
V (SRR)	\$ 7,203,000	\$11,344,000
VI (SRR)	\$ 3,500,000	\$ 6,882,000
VII (SRR)	\$ 6,640,000	\$14,383,000
II (SRR)-G	\$ 1,047,000	\$ 7,266,000
III (SRR)-G	\$ 5,688,000	\$10,656,000
IV (SRR)-G	\$ 3,360,000	\$ 5,106,000
V (SRR)-G	\$ 4,938,000	\$ 9,708,000
VI (SRR)-G	\$ 1,234,000	\$ 6,783,000
VII (SRR)-G	\$ 6,640,000	\$12,400,000

such periods, supply must depend almost entirely on ground-water and surface-water storage. While surface-water storage is useful in meeting peak demands, meeting daily demands for extended periods would require a prohibitively large reservoir. Thus, average demands must be satisfied entirely by ground-water sources. Year 2030 costs have been estimated to be $31,875,000 for Alternative II (Tennant).

Alternatives III (SRR) and IV (SRR) assume that all year 2000 and year 2030 deficits will be satisfied by surface-water sources. Under either scenario, a total of 650 acre-feet of usable storage is required in the year 2000 and 2,150 acre-feet is required in 2030. (These requirements decline to 450 acre-feet and 1,450 acre-feet with the Garrison Diversion.) As discussed in the previous section, approximately 450 acre-feet of usable storage is available behind the existing low-head dam.

Off-stream reservoir costs for Alternative III (SRR) are based on the design shown in Figure 13 in the previous chapter. Costs include land, earthwork, sitework, riprap, fencing, and landscaping, as well as raw water pumping and piping costs and system interconnections. In addition to West Fargo and Dilworth interconnections, a river crossing is included connecting the Fargo and Moorhead systems. Raw water is pumped from the reservoir to a treatment facility and then all four communities are served in a subregional system. The costs are $5,837,000 and $11,926,000 for Alternative III (SRR), or $5,688,000 and $10,656,000 with the Garrison Diversion.

A new dam will be needed to satisfy storage requirements for the in-stream reservoir alternative (Alternative IV (SRR)). The estimated costs for the improvements, including the dam, enlarged raw water pumping facilities and

interconnections to West Fargo and Dilworth, are $3,385,000 for the year 2000 demands and $5,235,000 for 2030 demands ($3,360,000 and $5,106,000, respectively, with the Garrison Diversion).

Alternative V (SRR) utilizes a combination of new sources to meet additional demands. These sources include increased development of the Kragnes, Moorhead, and Buffalo Aquifers, 450 acre-feet of storage behind the existing low-head dam, and a new 800 acre-foot off-stream storage reservoir. The estimated costs for these facilities are $7,203,000 for year 2000 demands and $11,344,000 for year 2030 demands. The costs associated with the Garrison Diversion variant of this alternative are $4,938,000 for year 2000 and $9,708,000 for year 2030 demands.

Alternative VI (SRR) uses the same aquifer development as in Alternative V (SRR) plus an enlarged storage reservoir behind a new low-head dam. The estimated costs for these facilities are $3,500,000 for year 2000 and $6,882,000 for year 2030 demands. The costs associated with the Garrison Diversion variant of this alternative are $1,234,000 for year 2000 and $6,783,000 for year 2030 demands.

Alternative VII (SRR) assumes no interconnection between the Fargo and Moorhead systems. Available Red River flows and reservoir storage are allocated to Fargo and Moorhead on a 70:30 basis, proportional to the population of each community. Withdrawals from the Sheyenne River and the West Fargo Aquifer are allocated to Fargo-West Fargo; Buffalo, Moorhead, and Kragnes Aquifer withdrawals are allocated to Moorhead-Dilworth. Under this scenario, Fargo-West Fargo would seek additional withdrawals from the West Fargo South Aquifer or from off-stream storage to meet year 2030 demands (no additional supplies are needed through year 2000). Moorhead-Dilworth would seek additional withdrawals from the

Moorhead, Kragnes, and Buffalo Aquifers. In extreme droughts when Red River streamflows fall below minimum in-stream requirements for extended periods, additional supplies will be required for Moorhead-Dilworth. An off-stream reservoir would be required to meet demands in both years 2000 and 2030. Estimated costs for Alternative VII (SRR) are $6,640,000 to meet year 2000 demands, increasing to $14,383,000 to meet year 2030 demands ($6,640,000 increasing to $12,400,000 with the Garrison Diversion).

B. SOCIAL IMPACTS

All water-supply alternatives are designed to meet the projected water supply deficits outlined for "no-action" conditions in Chapter VII. Therefore, impacts common to all alternatives include the social benefits realized from the mitigation of these water supply shortages. However, each proposed alternative uses a slightly different set of facilities to achieve this mitigation. Impacts directly associated with the construction and operation of these facilities must also be considered.

The social impacts under "no-action" conditions would be caused mainly by water shortages associated with droughts. Comparisons of "no-action" conditions and projected water demands reported in Chapter VII indicate that the peaking capabilities of facilities would be greatly exceeded. These water shortages are most likely to have the greatest influence on single large consumers and residential irrigators whose peak needs coincide with the drought period. Direct demographic impacts may be subtle. Economic impacts on commercial and industrial water users could be more pronounced since their large capital investment necessitates long-term planning regarding reliable supplies of water.

Direct demographic impacts under "no-action" conditions could include changes in community growth and cohesion. Urban core and rural water supplies have peak demand deficits that may discourage population growth. The smaller communities

are more susceptible to shortages. They are not able to take advantage of the economy of scale typical of large water supply facilities. These communities commonly deal with such small volumes of water that their ability to absorb additional flow requirements and associated costs is very limited. In addition, the stress from repeated water shortages may directly affect community cohesion. Community growth patterns may be affected as water for sprinkling becomes less available and as new developments feature smaller lawns, perhaps encouraging increased housing densities. More significant demographic impacts would likely occur indirectly as a result of economic impacts.

Economic impacts resulting from "no-action" conditions may directly affect future business and industrial activity, employment, and public services. In turn, other related economic impacts could include tax revenues and construction. Significant secondary impacts could also indirectly affect demographic conditions such as community/population growth patterns or community cohesion.

Industrial growth could be impeded by an unreliable water supply. Agricultural processing is presently a dominant industry and, hence, a probable growth industry. This type of industry commonly requires large volumes of water, so industrial expansion could be impeded by inadequate water supplies. This scenario is particularly applicable to Moorhead where the wastewater treatment facilities were recently expanded to accommodate projected increases in agricultural processing wastes. A related decrease in employment opportunities here could also spill over into supporting trade-services business activity and associated tax revenues or affect community growth potential. Construction employment could be indirectly affected also if employment opportunities are reduced greatly enough to hinder population growth.

Rural communities and local farming operations may suffer forgone profits if agricultural processors decline to locate in the study area. The increased transportation costs farmers would experience could make their products less competitively priced, subsequently decreasing market demand and local spendable income.

Social impacts of water supply alternatives also include those impacts directly attributable to the alternatives themselves. In addition to mitigation of the impacts related to "no-action" conditions, all water supply alternatives would insure adequate water supplies required by other important portions of the area's economy. Hospitals, colleges, and the service and trade sector as a whole are heavy water users.

Major social impacts related to implementation of the water supply alternatives stem from the need for inter-governmental cooperation in some alternatives. In particular, all alternatives except Alternative VII (SRR) would require a special agreement between Fargo and Moorhead, cities which are in different States. Such an agreement would form the basis for constructing an interconnection between the two cities' water systems and operating the interconnection as needed during drought periods. Feasible agreements of this type have previously been proposed between other North Dakota-Minnesota border communities (U.S. Army Corps of Engineers, 1981 b).

Interconnections from Fargo to West Fargo and from Moorhead to Dilworth are also included in the alternatives. These would require similar inter-city agreements but would each involve a pair of cities within one State. A Fargo-West Fargo interconnection could have very important ramifications.

The North Dakota State Water Commission is reportedly asking West Fargo to waive its water rights to 2,190 acre-feet of annual Sheyenne River flow and 952 acre-feet of Lake Ashtabula storage because of disuse. A West Fargo-Fargo interconnection might have some bearing on the retention or waiver of West Fargo's water rights and would offer West Fargo a reasonable means of meeting its future supply deficits.

Flooding is another important concern throughout the Red River of the North watershed. In this connection, in-stream reservoirs might be a concern. Alternative IV (SRR), for example, would enlarge the in-stream storage of the Red River reservoir in Fargo-Moorhead from the existing 600 acre-feet to 3,000 acre-feet. The existing low-head dam has a crest elevation of approximately 875 feet NGVD. Under Alternative IV (SRR), the new low-head dam would have a crest elevation of approximately 883 feet NGVD. Thus, the normal pool elevation would be raised by about 8 feet. Alternative VI (SRR) would enlarge the existing in-stream reservoir to 1,900 acre-feet. The new low-head dam's crest elevation would be approximately 880 feet NGVD under this alternative, about 5 feet above the existing dam's crest.

The Corps of Engineers, in cooperation with other Federal and State agencies and local governments, has developed a hydraulic model for analysis of flood events in the metropolitan area. This model could be used to analyze the effect of higher low-head dams on flood stages.

C. ENVIRONMENTAL IMPACTS

A key environmental parameter when evaluating water supply alternatives is the effect on streamflows and, consequently, biotic populations. Table 57 compares the effects on average Red River flows of using the Tennant minimum in-stream flow criteria versus the SRR criteria. Table 58 compares the effects in a

TABLE 57

COMPARISON OF RED RIVER FLOWS - MEAN MONTHLY STREAMFLOWS:
TENNANT CRITERIA VERSUS SOURIS-RED-RAINY (SRR) CRITERIA

Monthly River Flow Above Intakes (cfs)		Portion of River Flow Withdrawn at Intakes (cfs)		Flow Between Intakes and Treatment Plant Outfalls (cfs)		Flow Below Treatment Plant Outfalls (cfs)		Additional Flow With Tennant Criteria (cfs)
		Tennant	SRR	Tennant	SRR	Tennant	SRR	
Jan	180	12	31	168	149	196	177	19
Feb	180	12	31	168	154	196	182	14
Mar	590	31	31	559	559	587	587	0
Apr	1500	31	31	1469	1469	1497	1497	0
May	940	31	31	909	909	937	937	0
Jun	960	31	31	929	929	957	957	0
Jul	800	31	31	769	769	797	797	0
Aug	380	31	31	349	349	377	377	0
Sep	280	31	31	249	249	277	277	0
Oct	270	31	31	239	239	267	267	0
Nov	200	31	31	169	169	197	197	0
Dec	200	31	31	169	169	197	197	0

NOTE: Calculations utilize actual USGS flow data from stations on the Red River at Fargo and the Sheyenne River at West Fargo. When the flow withdrawn would bring flows in the Red River below 30 percent of mean annual flow, the Sheyenne River is utilized. Both rivers would then be reduced to the same percent of mean annual flow.

TABLE 58

COMPARISON OF RED RIVER FLOWS - DROUGHT CONDITIONS:
TENNANT CRITERIA VERSUS SOURIS-RED-RAINY (SRR) CRITERIA

Date	River Flow Above Intakes (cfs)	Portion of River Flow Withdrawn at Intakes (cfs)		Flow Between Intakes and Treatment Plant Outfalls (cfs)		Flow Below Treatment Plant Outfalls (cfs)		Additional Flow With Tennant Criteria (cfs)
		Tennant	SRR	Tennant	SRR	Tennant	SRR	
May 1976	340	31	31	309	309	337	337	0
June 1976	170	2	2	168	168	196	196	0
July 1976	91	0	0	91	91	119	119	0
August 1976	30	0	8	30	67	58	50	8
September 1976	12	0	5	12	7	40	35	5
October 1976	4	0	0	4	7	32	35	-3

NOTE: Calculations utilize actual USGS flow data from stations on the Red River at Fargo and the Sheyenne River at West Fargo. When the flow withdrawn would bring flows in the Red River below 30 percent of mean annual flow, the Sheyenne River is utilized. Both rivers would then be reduced to the same percent of mean annual flow.

October flows between intakes and outfalls demonstrate the effects of the in-stream reservoir. Under the SRR operating plan, water from the reservoir pool is released to maintain a minimum flow of 7 cfs. This produces greater flows than the Tennant criteria under those circumstances.

range of low flows which could represent a progressively worsening drought. Figure 16 graphically displays the relative effects in roughly this same low-flow range. These analyses consider the effect of the Sheyenne pipeline that supplies water from the Sheyenne River to the Fargo treatment plant.

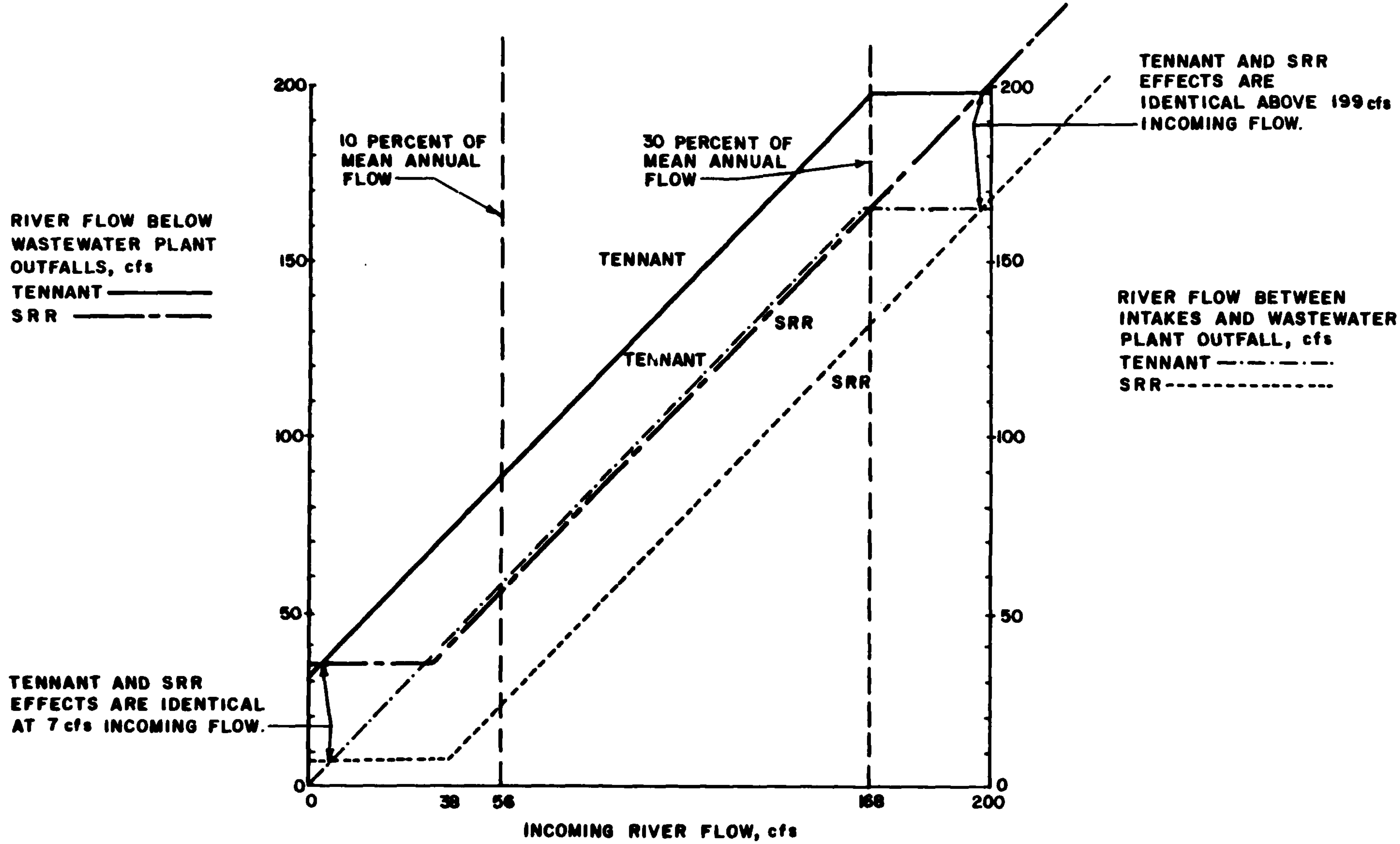
Three reaches in the Red River are of primary interest:

1. Upstream of the municipal water intakes (above the low-head dam) where river flow is unaffected by withdrawals.

2. In the 12-mile reach downstream of the municipal intakes (below the low-head dam) and upstream of the municipal wastewater treatment plant outfalls. The flow in this reach reflects withdrawals.

3. Downstream of the wastewater plant outfalls. The flow reflects treated wastewater return flows of the cities that discharge into the Red River. Historically, these flows average 70 to 80 percent of the total municipal demand of Fargo, Moorhead, and Dilworth (say 75 percent of 37.37 cfs, or about 28 cfs, in the year 2030).

In these comparisons, the Moorhead, Buffalo, West Fargo, and Kragnes Aquifers are fully developed; demands in excess of 95 percent of their average safe yield pumping rate would be met by river withdrawals under the SRR operating plan (about 31 cfs of the 40.73-cfs demand of the urban core communities of Fargo, West Fargo, Moorhead, and Dilworth in the year 2030). When the 31 cfs demand necessitates withdrawals that would bring Red River flows below 30 percent of mean annual flow, the Sheyenne River is utilized. Both rivers would then be reduced to the same percent of mean annual flow. The Tennant operating plan would allow no withdrawals that would reduce river flow below the 30-percent threshold.



FARGO-MOORHEAD URBAN WATER SUPPLY/CONSERVATION INVESTIGATIONS

RED RIVER DROUGHT FLOWS WITH TENNANT AND SRR OPERATING PLANS

E.A. HICKOK & ASSOCIATES
HYDROLOGISTS-ENGINEERS
MINNEAPOLIS-MINNESOTA

fig. 16

Points to note from these comparisons:

1. For incoming Red River flows above 199 cfs, the Tennant and SRR operating plans are identical and do not reduce flows below the 30-percent threshold.

2. In a typical year, incoming flows are significantly below 200 cfs only in January and February (Table 57). During those two months, the SRR plan would reduce flow in the 12-mile reach between the intakes and wastewater plant outfalls to approximately 27 percent of the annual mean. This slight flow deficiency (relative to Tennant's 30-percent threshold) probably would not have significant adverse effects on aquatic resources because at this time of year fish and aquatic plants have a lowered metabolism and are under less stress. Downstream of the outfalls, both plans would keep flows above the 30-percent threshold. Therefore, under normal conditions, the choice of operating plan would make little difference in terms of impacts on aquatic resources.

3. For incoming flows between 7 and 199 cfs, the Tennant operating plan results in up to 31 cfs more flow than the SRR operating plan (Figure 16). Although river flow in much of this range would be below the 30-percent threshold with either operating plan, the additional flow with the Tennant plan could significantly improve the viability of sensitive species.

4. If incoming flow drops below 7 cfs, municipal withdrawals cease under both operating plans. With the Tennant operating plan, flow in the 12-mile reach between the intakes and wastewater plant outfalls is the same as the incoming flow. However, with one exception, alternatives using the SRR operating plan were designed with sufficient capacity to augment river flows and maintain 7 cfs in this 12-mile reach. (Tennant-based alternatives

could also be modified to maintain some specific river flow; this augmentation would require additional storage or source development.) The wastewater plant would release about 28 cfs, more than quadrupling the natural or augmented river flow at and below this point. Regardless of the operating plan, with a low-flow situation of this severity, flows in the river would be below even the 10-percent threshold that Tennant suggests is needed for short-term survival of most fish species (Chapter VI).

How often can low-flow situations occur? Analyses show that every other year on the average (i.e., a 2-year drought), the Red River incoming flow could average below the 30-percent (168-cfs) threshold for about 6 months. In a 10-year drought, flows would average below 168 cfs for 2 years and below 7 cfs for over 2 weeks. In the 50-year design drought, flows would average below 168 cfs for over 8 years.

For comparison, in the 1976-1979 drought, the Red River was essentially dry for 7 months. Water stored in Lake Ashtabula was released to augment Sheyenne River flows, and Fargo used the Sheyenne diversion to route about 25 cfs into the Red River to meet municipal demands. Flows in the Red River would have required partial or total cessation of municipal withdrawals with the Tennant operating plan for 32 of the 33 months between June 1976 and February 1979, including one stretch of 22 consecutive months. With the SRR operating plan, there would have been 15 months of partial or total cessation of withdrawals, including one span of 7 consecutive months.

Surface-water alternatives would meet future water supply deficits by using water from the Red and Sheyenne Rivers. These alternatives can be based on off-stream reservoirs or in-stream reservoirs or a combination of both types. Regardless of the reservoir type, aquatic impacts could be reduced if the reservoirs were filled when streamflows were high instead of deferring filling until a drought has already reduced flows considerably.

The construction of off-stream reservoirs, pipelines, and water storage facilities and the expansion of the existing water treatment facilities should have little direct effect on fish and wildlife resources. The habitat affected by these structures should not be unduly extensive if judicious planning is used. The water intake structure for the off-stream reservoir at the river should be installed to minimize any damage or loss of fish resources. Fry and fish eggs could be drawn into the intake, causing losses in fish production. To minimize losses, an intake structure should be designed so that the approach velocity cannot exceed 0.5 foot per second (fps) immediately in front of the screen. An intake screen with a maximum opening of one-quarter inch will minimize fish entrainment. The intake should be placed at the greatest practicable depth.

The existing low-head dam at Fargo creates a barrier to fish movements under all but high-flow conditions. A higher structure would probably exacerbate the problem. A low-head dam does not present a barrier to fish movement during floods when the structure would be submerged. However, under normal or low-flow conditions, fish spawning runs into the tributaries and upper reaches of the Red River could be prevented from proceeding beyond the dam. Fishways could be engineered into the design of the dam to allow for fish passage over or through such a barrier. In general, the entrance to a fishway is most important. The entrance cannot be too far downstream of the barrier, too far from the main streamflow, in a back eddy, or too high. A collapsable weir makes a good fishway through a barrier.

Alternative IV (SRR)'s 3,000 acre-foot in-stream reservoir would be higher than the primary banks and extend outside the river channel. This pool would inundate or saturate the root zone of a significant amount of riparian

vegetation. This would cause the loss of a large portion of the riparian wildlife habitat, which is by far the most important (and frequently the only) remaining wildlife habitat in the area. In addition, this pool could increase bank erosion and stability problems alongside the raised pool. Saturated banks might have a greater tendency to slump into the river, increasing turbidity and sedimentation. This would have an adverse effect on the terrestrial and aquatic resources of the area.

Preliminary data suggest that Alternative VI (SRR)'s 1,900 acre-foot reservoir would be within the primary banks. The impacts associated with this lower pool elevation would be substantially less than with Alternative IV (SRR). Some streambank vegetation would be lost due to inundation, but the majority of the riparian habitat would remain unaffected.

An in-stream reservoir slightly larger than the existing one has some features that would be favorable to fish and wildlife. The elongated pool would provide resting, feeding, and nursery waters. The greater pool depth would encourage greater numbers of game fish by concentrating species during droughts; however, this concentration would make them more susceptible to overharvesting.

Riparian vegetation might receive some benefits from an in-stream reservoir because, in a drought, the soil's water level would remain closer to the root zone. Wildlife would also benefit from the more permanent source of water. The increased water level would insure that islands remain surrounded by water and continue to serve as nesting, denning, nursery, and refuge habitat for wildlife. The pool would provide resting and feeding areas for numerous waterfowl that pass through the study area during spring and fall migration periods.

Oxbows, drained or existing, could serve as a series of in-stream reservoirs. Insofar as practicable, backwater areas should be protected because of their important value as nursery waters. Water control inlets and outlets could be

installed in each of the oxbows. Raw water would enter the oxbow for storage during high or plentiful flows. When municipal demands would require more water, the oxbows would be allowed to release their stored water into the river's channel. The downstream treatment plant would then draw the water in through its intake system. When streamflows would be adequate for municipal needs, the oxbow could be used to augment very low streamflows harmful to the movement and oxygen needs of fish and invertebrates.

Some of the alternatives include dredging to maintain adequate storage in the in-stream reservoir. Extensive dredging could affect aquatic resources by destroying spawning habitat. However, dredging is not expected to be extensive and would probably be conducted near the low-head dam, so the impacts are not anticipated to be significant.

Prior studies provide only limited information about the possibility of ground-water withdrawals affecting area streamflows. Available work indicates that ground-water well field withdrawals of the proposed alternatives would have no direct effect on streamflows or other surface water except in unusual circumstances where the geologic and hydrologic conditions combine to affect streamflows.

The most likely area to find such conditions in this region would be in the vicinity of the Sheyenne Delta Aquifer. In the Sheyenne delta area, movement of ground water to the surface contributes to streamflow during periods of low flow. During high streamflows and surface runoff, water percolates into the aquifer and recharges it. The many spring-fed streams in the delta area and the high water table provide habitat for fish and unique growing conditions for vegetation. Because of this, the delta area provides habitat for rare species of vegetation and wildlife which are unique in eastern North Dakota.

Alternatives which would tap the Sheyenne Delta Aquifer are not expected to cause significant impacts because they would withdraw less than one-fourth of the estimated safe yield. If withdrawals should ever approach the safe yield or if wells are poorly located so that they cause localized declines of the water table, serious impacts could occur. However, judicious planning of well placement would eliminate these potential problems.

D. RECREATIONAL IMPACTS

No recreational opportunities or impacts are directly related to the ground-water developments required for certain alternatives. However, both off-stream and in-stream reservoirs can offer additional opportunities. An off-stream reservoir could be used for recreational activities such as swimming, fishing, and non-motorized boating if the reservoir was appropriately designed and managed. Thus, the reservoir could become the focal point for a large park that could be of regional significance. A recreational development scenario would have the reservoir designed with an irregular shoreline, and the bottom would be shaped for fisheries management. Maximum reservoir depths would be approximately 20 feet, giving fish an adequate environment. A minimum depth of 15 feet is marginal to prevent fish kills in cold climates. A put-and-take stocking program could be developed to create and enhance the opportunity for urban fishing. More would have to be known about the expected water levels in the reservoir and their compatibility with the needs of stocked fish. A swimming beach with a gentle bottom slope could be created along a portion of the shoreline. Sufficient lands adjacent to the reservoir would be acquired to support related recreational activities such as picnicking, boat launching, fishing, and parking. The pipeline corridors could serve a dual purpose as trail corridors from the urban areas to the park.

An off-stream reservoir is also beneficial to wildlife. A broader beach around the reservoir would enhance its usefulness to waterfowl and some shorebirds. The construction of islands within the reservoir would encourage waterfowl loafing and possibly some nesting.

An in-stream reservoir would provide greater water surface for water-based recreational activities such as fishing and boating. Of primary concern would be the significant safety hazards inherent with low-head dams: the low visibility of the crest from upstream and the recirulating hydraulic current extending across the stream below the dam. During design phases, serious consideration should be given to increasing the visibility of the structure to boaters and to disrupting the recirculating current. One approach would be to provide an irregular crest. The irregularity would be more visible to boaters. Also, the uneven flows over the crest would result in eddy flows below the structure. The result would be a safer structure from a boating perspective. Additionally, the structure would be more aesthetically appealing.

Given the proposed reservoir's size, considerable shoreline would be available for water-oriented recreation such as bank fishing, picnicking, and swimming. Consideration should be given to changing the channel's configuration to provide for greater usability. For example, deep, fish-holding pools could be created and bank-fishing facilities provided adjacent to them. Also, pools/lagoons could be created adjacent to the main channel for swimming areas, wildlife and/or fisheries habitat, or as aesthetic amenities.

E. <u>CULTURAL IMPACTS</u>

Specific cultural impacts to prehistoric and historic archaeological sites and historic standing structures cannot be determined at this time. However, there is potential for significant impacts to cultural resoures from any ground-

disturbing activities associated with well field or low-head dam construction, pipe laying, and in- or off-stream reservoirs. The in-stream reservoir is a particular concern because past surveys have located sites along the Red River. Areas possibly affected by recommended alternatives will need to be surveyed for cultural resources. Those sites that would be impacted and are listed on or determined to be eligible for inclusion on the National Register would be mitigated in accordance with the Advisory Council on Historic Preservation Regulation 36 CFR 800.

X. EVALUATION OF ALTERNATIVES

A. SCREENING OF ALTERNATIVES

The cost estimates previously presented in Table 56 indicate the alternative-specific capital costs required to meet year 2000 and 2030 demands. Alternatives IV (SRR), VI (SRR), and II (SRR) are the least-cost alternatives in the near term. Over the long term, Alternatives IV (SRR) and VI (SRR) are clearly the least-cost alternatives.

It is not surprising that in-stream storage is a component of the least-cost alternative. As demands increase, off-stream reservoirs require larger pipes, incurring higher piping and pumping costs. Ground-water sources also require both larger and longer piping systems. For large water deficits, these measures are not competitive. In contrast, incremental costs for added storage with in-stream reservoirs are quite small (for example, the difference between the costs of building a dam 17 feet high or 17.5 feet high is not significant). With an in-stream reservoir, the supply is located nearer to the water treatment plant, and existing piping facilities can be used for the near term, so transmission costs are also significantly lower.

Based on relative costs, Alternatives IV (SRR) and VI (SRR) would be the likeliest candidates for local implementation. Alternative II (Tennant), the least costly Tennant-based alternative, is also retained for consideration. This alternative provides a basis for comparing the environmental advantages of Tennant-based alternatives in relation to the economic trade-offs.

Alternatives IV (SRR) and VI (SRR) require a larger low-head dam than presently exists. Alternative IV (SRR) requires approximately 3,000 acre-feet of total storage; Alternative VI (SRR) requires approximately 1,900 acre-feet. The difference between the two alternatives, besides the size of the in-stream

reservoirs, is the timing of major capital expenses. Alternative IV (SRR) requires the construction of the larger dam in the near term. Alternative VI (SRR) meets near term needs through expansion of existing well fields. In Alternative VI (SRR), the low-head dam would not be constructed until late in the 50-year planning period. The effect of this timing is to make the present worth and annualized costs of Alternatives IV (SRR) and VI (SRR) essentially equal (Table 59). Therefore, economics is not a factor in choosing between these two alternatives.

Source dependability is an important consideration in weighing relative advantages and disadvantages. Alternative IV (SRR) relies almost exclusively on streamflows, which are less dependable than ground water. Alternative VI (SRR), which uses both surface and ground water, would likely be more dependable than IV (SRR). Alternative II (Tennant), which is based largely on ground water, likely would be the most dependable of these three alternatives.

In-stream reservoirs, particularly a larger one like that of Alternative IV (SRR), have adverse impacts which offset their economic advantages. Alternative IV (SRR)'s 3,000 acre-foot reservoir would extend outside the Red River's primary streambanks for several miles. Natural resources agencies indicate that the resulting destruction of significant riparian habitat would not be acceptable. Preliminary evidence shows that Alternative VI (SRR)'s 1,900 acre-foot reservoir would not overtop the primary streambanks. Alternative VI (SRR)'s smaller reservoir also would reduce adverse social impacts associated, for example, with inundation of private property.

An alternative's effect on streamflows and, therefore, on aquatic resources is of major concern. This subject is discussed in detail in Chapter IX. When Red River flow entering the urban core exceeds 199 cfs, Alternative II (Tennant)

TABLE 59

COMPARATIVE PRESENT VALUE COSTS
ALTERNATIVES IV (SRR) AND VI (SRR)

	Alternative IV (SRR)	Alternative VI (SRR)
1985		
Fargo-West Fargo Connection	$ 378,000	$ 378,000
Moorhead-Dilworth Connection	$ 31,000	$ 31,000
	$ 409,000	$ 409,000
1990		
New Low-Head Dam (3,000 acre-feet)	$2,960,000	
Raw Water Pumping	$ 374,000	$ 266,000
Moorhead Well Field Expansion		$ 230,000
Buffalo Well Field Expansion		$1,838,000
Fargo-Moorhead Connection		$ 468,000
	$3,334,000	$2,802,000
2000		
Buffalo Well Field Expansion		$ 721,000
2010		
New Low-Head Dam (1,900 acre-feet)		$2,800,000
Raw Water Piping	$1,492,000	$ 150,000
	$1,492,000	$2,950,000
Total Cost	$5,235,000	$6,882,000
Present Worth at 9.352 Percent	$2,470,000	$2,474,000
Annual Equivalent at 9.352 Percent on 46 Years	$ 234,800	$ 235,200

and Alternatives IV (SRR) and VI (SRR) would have identical effects and would not reduce flows below Tennant's 30-percent threshold. With an incoming flow between 7 and 199 cfs, Alternative II (Tennant) would maintain up to 31 cfs more flow below the municipal intakes than Alternatives IV (SRR) and VI (SRR) (based on year 2030 figures). If incoming flow dropped below 7 cfs, Alternatives IV (SRR) and VI (SRR) would augment streamflow to 7 cfs in the 12-mile reach between the intakes and the wastewater treatment plant outfalls; Alternative II (Tennant) would allow flow to continue to fall, possibly to zero. Downstream of the wastewater treatment plant outfalls, all three alternatives would supplement flow with as much as 28 cfs, but Alternatives IV (SRR) and VI (SRR) would begin to supplement only when incoming flows were below 38 cfs, whereas Alternative II (Tennant) would supplement flows up to 199 cfs.

Based on streamflow effects, Alternative II (Tennant) would be preferred because, except in the most serious of droughts, it would maintain somewhat higher flows for longer periods. However, none of the alternatives is designed to maintain Tennant's 30-percent flow for good survival habitat or even the 10-percent flow for limited survival of fish resources. Therefore, severe droughts will continue to pose a serious threat to the fishery regardless of alternative.

Based on the above evaluation, including such factors as costs, dependability, and environmental and social impacts, Alternatives II (Tennant) and VI (SRR) have been retained for consideration. The next section provides a more detailed cost breakdown for Alternative VI (SRR), the more cost-effective of the two. The following chapter describes drought emergency plans for both alternatives.

B. DETAILED COSTS FOR ALTERNATIVE VI (SRR)

Detailed costs for Alternative VI (SRR) are presented for two purposes. First, they provide the communities with an estimate of the future capital outlays required to meet water supply needs through the year 2030. Second, they provide a basis for determining foregone costs of supply in Phase 3 of this study when total costs of conservation are evaluated against total benefits.

Table 60 presents costs for Alternative VI (SRR). These costs are more detailed than costs presented thus far because they include costs for water treatment, costs for small community facilities, costs for operation, maintenance and repair (O, M & R), and costs for equipment replacement.* An effort has also been made to determine the timing for expenditures more closely. Previously, timing for expenditures was rounded to the nearest earlier 5 or 10-year increment. Timing in Table 60 is estimated to the nearest year. It must be emphasized that population and water consumption projections cannot accurately predict needed expenditures to the nearest year, but yearly estimates are required to determine foregone water supply costs associated with water conservation (foregone supply costs will be discussed further in Phase 3 of this study). Figure 17 presents a graphical picture of the timing of the expenditures outlined in Table 60.

Cost estimates are based on cost curves, published unit cost data, manufacturer and supplier information, and recent bid experience on similar construction. All costs are presented in 1984 dollars. Construction costs include such items as earthwork, river diversion, concrete, sheet piling, wells, pipelines, pumps, purchase and installation of equipment, replacement of worn out equipment,

*Equipment replacement costs are included in capital costs in this analysis. Some agencies prefer to show these as O, M, & R costs. The footnote to Table 60 discusses the effect of the alternate ways of presenting replacement costs.

TABLE 60

DETAILED COST ESTIMATES FOR ALTERNATIVE VI (SRR)

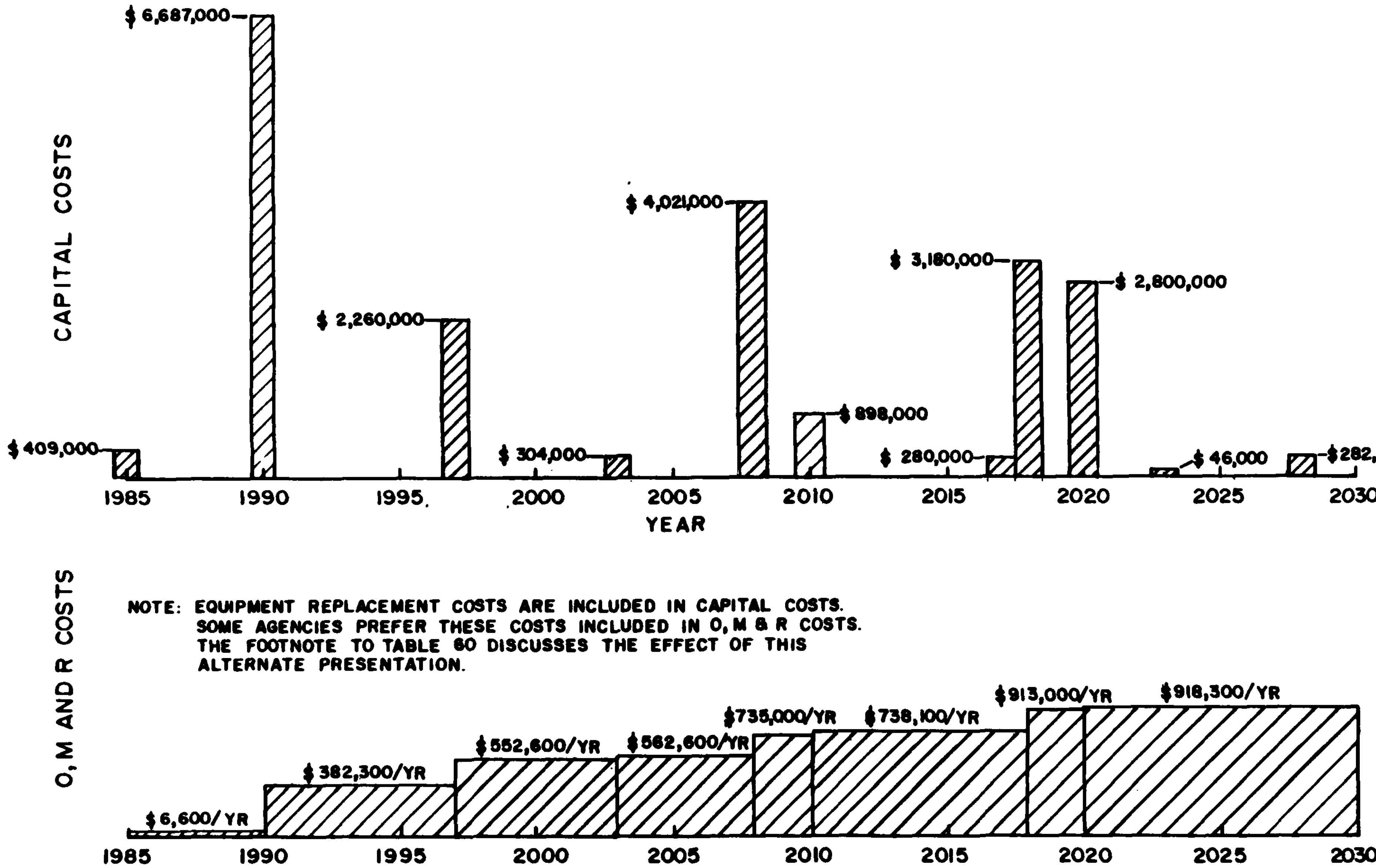
Approximate Timing	Facilities	Construction* Cost	O, M and R Costs
1985	Fargo-West Fargo Connection	$ 378,000	$ 6,100
	Moorhead-Dilworth Connection	$ 31,000	$ 500
1990	Fargo-Moorhead Connection	$ 468,000	$ 4,800
	Fargo Raw Water Piping Expansion	$ 106,000	$ 1,300
	Fargo Water Treatment Plant Expansion (10 mgd)	$ 4,984,000	$ 350,400
	Dilworth Elevated Storage (0.4 mg)	$ 450,000	$ 2,300
	Sabin Well, Ground Storage and Booster Pump	$ 235,000	$ 6,600
	Glyndon Ground Storage and Booster Pump	$ 188,000	$ 2,700
	Riverside Well, Ground Storage and Booster Pump	$ 140,000	$ 6,000
	Horace, Ground Storage and Booster Pump	$ 116,000	$ 1,600
1997	Moorhead Water Treatment Plant Expansion (4 mgd)	$ 2,030,000	$ 155,500
	Moorhead Well Field Expansion (0.9 mgd)	$ 230,000	$ 14,800
2003	Buffalo Well Field Expansion (0.6 mgd)	$ 304,000	$ 10,000
2008	Buffalo Well Field Expansion (2.1 mgd)	$ 1,991,000	$ 16,900
	Moorhead Water Treatment Plant Expansion (4 mgd)	$ 2,030,000	$ 155,500
2010	Horace Well	$ 47,000	$ 3,100
	Sabin Pump Replacement	$ 46,000	$ --
	Glyndon Pump Replacement	$ 49,000	$ --
	Riverside Pump Replacement	$ 25,000	$ --

TABLE 60 (continued)

DETAILED COST ESTIMATES FOR ALTERNATIVE VI (SRR)

Approximate Timing	Facilities	Construction* Cost	O, M, and R Costs
	Fargo WTP Equipment Replacement	$ 731,000	--
2017	Moorhead Well Field Pump Replacement	$ 90,000	--
	Moorhead WTP Equipment Replacement	$ 190,000	--
2018	Fargo Water Treatment Plant Expansion (5 mgd)	$ 3,180,000	$ 175,200
2020	Reconstruct Larger Low-Head Dam	$ 2,800,000	$ 5,000
2023	Buffalo Well Field Pump Replacement	$ 46,000	--
2028	Buffalo Well Field Pump Replacement	$ 92,000	--
	Moorhead WTP Equipment Replacement	$ 190,000	--
	TOTAL	$21,167,000	$ 918,300
	Present Value Equivalent	$ 5,891,000	$3,154,000
	Uniform Annual Equivalent	$ 560,100	$ 299,900

*Equipment replacement costs are included in construction costs. Some agencies prefer these costs included with O, M, & R costs. Including these costs with O, M, & R would increase the O, M, & R present value equivalent by $109,000 and the uniform annual equivalent by $10,400. It would decrease the construction costs by the same amount, leaving the total present value and uniform annual equivalents unchanged. The capital costs shown in Figure 17 would be decreased, but corresponding capital outlays to the O, M, & R costs would be added.



NOTE: EQUIPMENT REPLACEMENT COSTS ARE INCLUDED IN CAPITAL COSTS. SOME AGENCIES PREFER THESE COSTS INCLUDED IN O, M & R COSTS. THE FOOTNOTE TO TABLE 60 DISCUSSES THE EFFECT OF THIS ALTERNATE PRESENTATION.

FARGO-MOORHEAD URBAN WATER SUPPLY/CONSERVATION INVESTIGATIONS

CAPITAL OUTLAYS FOR ALTERNATIVE VI (SRR)

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MINNEAPOLIS - MINNESOTA

fig. 17

electrical work, site work, contractor's overhead and profit, engineering, legal and fiscal services, and administration. Operation, maintenance, and repair costs include expenditures for routine operations, maintenance and minor repairs, labor, electrical power, chemicals, and required materials.

A present value of these costs at the Federal discount rate of 9.352 percent is $5,891,000 for capital costs and $3,154,000 for operation, maintenance, and repair costs. Total present value costs are $9,045,000, which is equivalent to approximately $860,000 per year at the Federal discount rate over a 46-year planning period.

XI. DROUGHT EMERGENCY PLANS

A. GENERAL

The purpose of drought emergency plans is to minimize the losses experienced by communities due to water supply deficits experienced during droughts. The two means of fulfilling this purpose are to conserve water and to augment supply with emergency sources. Both means are employed here.

Drought emergency plans are constructed by using a supply augmentation plan as an operational framework. The augmentation plan outlines the order and degree of development of the available emergency water supplies in a manner that minimizes costs. Water conservation measures are combined with the augmentation plan. These measures increase the efficiency of the emergency plan by reducing demand at opportune points within the augmentation plan. Generally, as the drought lengthens, more costly means of augmentation must be developed and more extensive conservation measures are implemented. Efforts are taken to ensure that these conservation measures are applied equitably to all types of consumers.

In this section, two water supply augmentation alternatives are examined in drought emergency plans. One drought emergency plan is proposed for the rural communities while two different plans are presented for the urban core communities. The first urban emergency plan is based on water supply Alternative VI (SRR) and the second is based on Alternative II (Tennant). Both of these alternatives are described in detail in Section VIII. The conservation measures that are combined with these alternatives are measures commonly taken by communities to mitigate supply deficits during drought. A more comprehensive approach to water conservation is provided in Phase 3 of the

Fargo-Moorhead Urban Study's water supply/conservation investigation, wherein conservation measures are incorporated directly into the water supply plan; modified drought emergency plans are also developed.

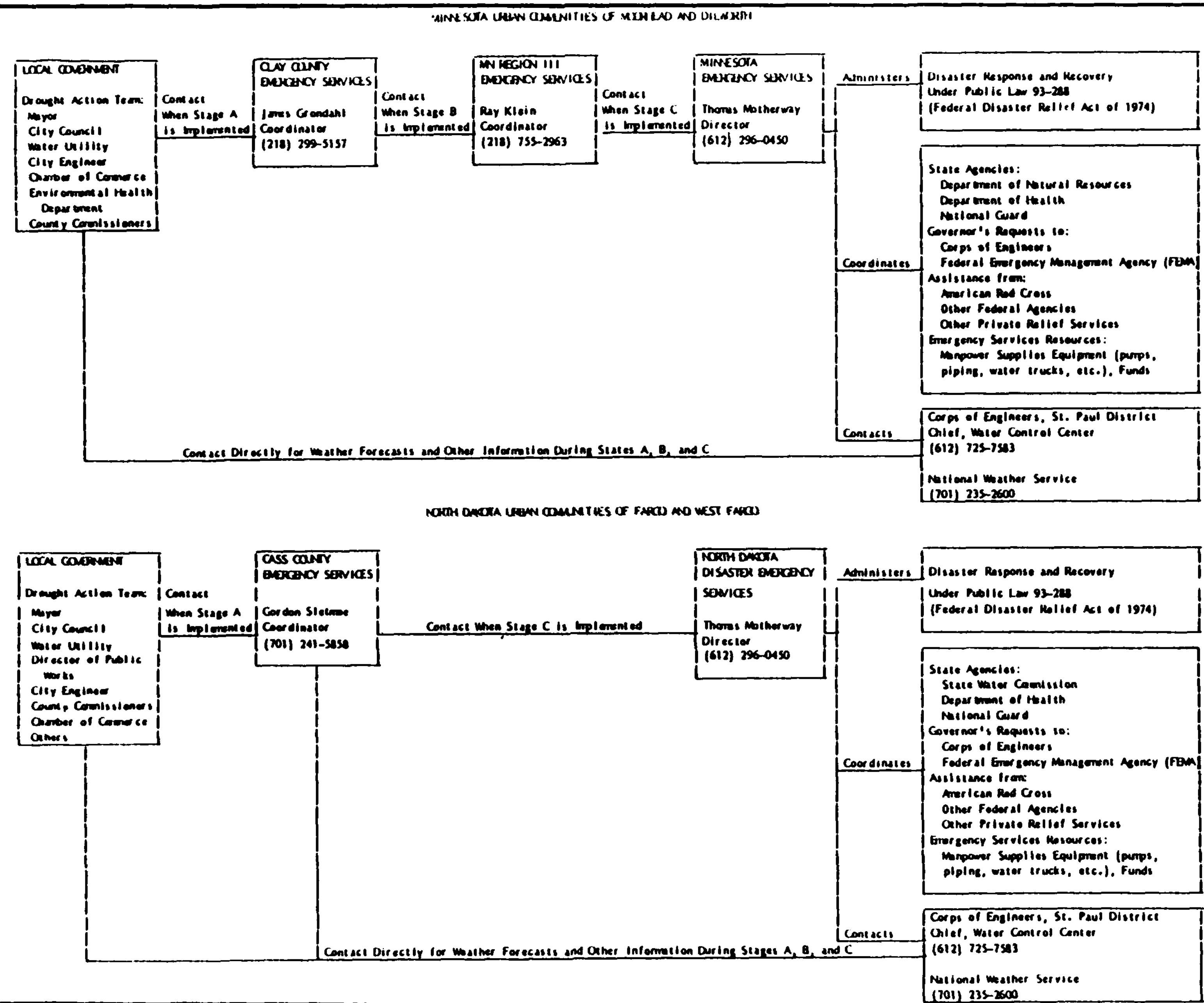
Essentially, all rural communities obtain their water supplies from ground water and, hence, are not directly affected by drought. Rural communities could be affected secondarily as demands on aquifers by others increase in response to drought. For this reason, the general term "Emergency Water Supply Plan" is applied to the drought emergency plans associated with rural communities. Rural communities are also subject to water shortages associated with contamination of their well fields or facility failure. Since the rural communities were treated similarly in water supply Alternatives VI (SRR) and II (Tennant), only one Emergency Water Supply Plan is proposed. This plan uses a conservation program patterned after the urban community program and is presented in the subsection following the discussion of the urban plans.

B. DROUGHT EMERGENCY PLANS FOR URBAN CORE COMMUNITIES

1. General

The drought emergency plans for urban core communities are intended to address conditions encountered during a 50-year drought. Effective public sector actions are vital to the success of drought emergency plans. The current supply conditions must be analyzed and the public must be well informed about the drought and what actions are to be taken.

All stages in the drought emergency plan utilize a network of contacts necessary to disseminate and obtain information pertinent to local drought actions. Figure 18 displays the networks for Minnesota and North Dakota urban core communities.



FARGO-MOORHEAD URBAN WATER SUPPLY/CONSERVATION INVESTIGATION

DROUGHT ACTION ORGANIZATION CHART

E.A. HICKOK & ASSOCIATES
HYDROLOGISTS-ENGINEERS
MINNEAPOLIS-MINNESOTA

fig. 18

The network displays governmental entities which can be of assistance in a drought emergency, including local, county, regional, State, and Federal agencies. The assistance they can provide includes general information on weather and streamflow forecasts and reservoir operation, as well as technical and financial aid such as planning, manpower, supplies, equipment, and funds. However, before outside assistance can be obtained, local governments must use all possible local resources to combat water supply deficits.

Local governments, specifically mayors, have the ultimate responsibility for directing the drought emergency plan, though in certain cases, the mayor may appoint a qualified local official to direct the plan. As water supplies dwindle, local governments should undertake the following actions:

1. Monitor weather forecasts, streamflows, and reservoir operation. This information should be obtained through the National Weather Service and Corps of Engineers.

2. Implement the "Public Sector Actions" outlined in the Drought Emergency Plan and commit the required local resources including funds, manpower, and equipment.

3. Contact local emergency services coordinators.

4. Declare a drought emergency.

As the drought condition becomes more severe and local capabilities become extended, outside assistance should be obtained. Requests for technical and financial aid from State and Federal agencies must be handled through the Cass and Clay County Emergency Services offices.

The coordinators in these offices should be kept informed of the problems that occur as the drought condition becomes more severe, so they can relay this information to the State and Federal coordinators when assistance is requested. Before State and Federal aid can be requested, local governments must declare a drought emergency or disaster. Then local governments should follow the procedures already developed by North Dakota and Minnesota emergency services agencies.

The local, regional, State, and Federal emergency service agencies shown in Figure 18 play an important role during a drought. These agencies help local governments assess the drought conditions, coordinate outside efforts, and provide technical and financial assistance. The specific responsibilities and types of assistance provided by these agencies are outlined below.

The North Dakota Disaster Emergency Services includes county and State offices which, as a team, assist local governments during drought emergencies. The State office becomes involved when the emergency exceeds the local coordinators' capabilities. The county and State offices should be primary advisors to local governments concerning drought conditions and procedures for initiating the Drought Emergency Plan. The assistance they provide includes the following:

1. Advise local governments on procedures, available relief services, and other sources of aid.

2. Assess the drought condition and recommend appropriate action.

3. Administer disaster response and recovery programs under Public Law 93-288 (Federal Disaster Relief Act of 1974).

4. Advise and make recommendations to the Governor that he:

   a. Petition the Corps of Engineers to make emergency releases from its reservoirs.

   b. Request involvement of State agencies and obtain their assistance as needed. These include, but are not limited to, the following:

      State Water Commission
      Department of Health
      National Guard

   c. Appoint an "on-site" coordinator and assessment team composed of representatives from various State agencies. This team assesses drought conditions and directs use of State resources.

   d. Request a Presidential declaration of a major disaster or an emergency when the drought condition becomes severe enough, so that the Federal Emergency Management Agency (FEMA) can become involved.

   e. Prepare to promote legislation which may be needed to mitigate drought conditions.

5. Coordinate the assistance provided by State and Federal agencies directly to the affected area such as manpower, supplies, equipment, and technical assistance.

6. Implement the procedures outlined in the <u>North Dakota: Disaster Procedure Handbook I</u> and <u>North Dakota: Disaster Plan</u>.

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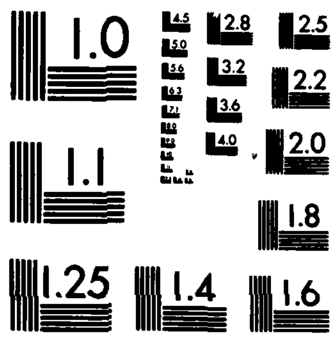

MICROCOPY RESOLUTION TEST CHART

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The North Dakota State Water Commission is responsible for managing the State's waters and administering State policies which allocate water on the basis of a permit system. This permit system allocates water to the earliest dated permit first.

The Minnesota Emergency Services (MES) includes county, regional, and State offices which, as a team, assist local governments during drought emergencies. The next higher level office becomes involved as the preceding office's capabilities are exceeded. MES should be a primary advisor to local governments concerning drought conditions and procedures for mitigating the drought. MES assistance is similar to that provided by the North Dakota Disaster Emergency Services. However, State financial aid is available through application to the State Executive Council. The regional director of emergency services is responsible for directing State resources in the affected area. MES procedures are outlined in the Minnesota Disaster Emergency Plan.

In Minnesota, the Department of Natural Resources is responsible for the waters of the State and provides many of the same services as the North Dakota State Water Commission. Minnesota retains control of State waters and has the authority to allocate the use of these waters on the basis of an established priority system during drought. In this system, residential water needs have first priority.

The North Dakota and Minnesota Departments of Health have jurisdiction over municipal and public drinking water supplies and waste disposal systems. These agencies can provide assistance in instances of contamination and for determining treatment requirements for sources of water supply.

The North Dakota and Minnesota National Guards can obtain, transport, and distribute potable water during extreme drought conditions. The National Guard could also assist in inspection efforts required by water demand reduction measures.

The Corps of Engineers plays a major role in combating droughts in the urban area. The Corps can provide general information obtained from other Federal agencies. This information includes weather forecasts, streamflow data, reservoir operation, and reservoir levels. The Corps obtains data from the National Weather Service, the U.S. Geological Survey, and other Corps branches. These data can also be obtained directly by the local governments through the individual agencies. Other assistance provided by the Corps must be coordinated through the emergency services agencies and the Governors of the two States. This assistance might include "providing emergency releases" of water from the reservoirs upstream of the urban area including Orwell Lake, Lake Traverse, and Lake Ashtabula.

FEMA is the primary Federal agency responsible for mitigating major disaster and emergency conditions. It coordinates and directs all Federal assistance and advises local governments on the availability of Federal programs, assistance, and financial aid. Its assistance is provided through regional offices. North Dakota is served by Region 8, headquartered in Denver, Colorado. Minnesota is served by Region 5, headquartered in Chicago, Illinois. FEMA becomes involved after State government capabilities have been exceeded. The Governor requests a presidential declaration of a major disaster or emergency through the FEMA regional offices. The national administrator assesses the drought

condition and makes a recommendation to the Secretary of Housing and Urban Development, who recommends action to and by the President. If the conditions warrant and the President declares a major disaster or emergency, the counties which are designated become eligible for Federal disaster assistance and other Federal relief efforts.

A vast array of Federal programs is available for specific and specialized disaster and/or emergency conditions. These programs are listed in the report entitled, Digest of Federal Disaster Assistance Programs, which can be obtained from the FEMA regional offices or the Minnesota and North Dakota emergency services agencies.

The U.S. Geological Survey monitors streamflows on both the Red River of the North and Sheyenne River. Area offices provide the Corps with data monitored by the USGS gaging stations near Fargo and West Fargo. These data may be supplied to local officials on request through the Corps or directly from the Geological Survey.

The American Red Cross, Salvation Army, and other private relief agencies can assist local governments and individuals who are affected by droughts. These agencies can provide food, shelter, clothing, and medical care, and assistance in law enforcement, fire fighting, rescue, manpower, and communications.

2. Drought Emergency Plan - Water Supply Alternative VI (SRR)

Alternative VI (SRR) is capable of providing for the projected needs of the urban core communities during a 50-year drought through the year 2030. Therefore, the demand reductions provided by water conservation measures can be applied as a margin of safety toward a 100-year or greater recurrence interval

event. There are four important stages in this Drought Emergency Plan. These stages are outlined in Table 61 and are described in detail in the following discussion.

Stage A is implemented when the sum of the available ground-water and streamflow supplies just equals the demands of the urban core communities. Available ground water, as described in Chapter VIII, consists of withdrawals at 95 percent of the safe yield rates from the Buffalo, West Fargo, Moorhead, and Kragnes Aquifers less other major uses. Available streamflow includes the combined Red and Sheyenne River flows less the 7- and 3-cfs minimum in-stream flows designated by the Souris-Red-Rainy River Basins Comprehensive Study. Additional deficits caused by the continuing drought conditions must be met from storage. This storage includes the in-stream storage behind the low-head dam on the Red River and the volume of water reserved in the developed aquifers by limiting average annual withdrawals to 95 percent of safe yield.

Public sector actions include information/education campaigns and the utilities' water conservation programs. In Stage A, the Drought Action Teams meet in the Minnesota and North Dakota portions of the urban area. The teams contact the County Emergency Services Offices and assist the cities in publicizing the current status of water supply facilities. In Stage A, their primary purpose is to alert the public of potential water shortages. The utilities increase their maintenance and repair programs to reduce losses and demonstrate a commitment to mitigate any potential shortages.

Stage B is implemented when the combined supply from the sources outlined in Stage A is less than the demands of the urban core communities. The low-head storage behind the Red River low-head dam must now be utilized to cover deficits.

TABLE 61

DROUGHT EMERGENCY PLAN - URBAN CORE COMMUNITIES

CURRENT CONDITIONS	PUBLIC SECTOR ACTIONS
STAGE A	
WITH SUPPLY ALTERNATIVE VI (SRR)	
Combined supplies from all sources utilized under standard operating conditions approach 100 percent of the demand of the urban core communities: The following aquifers are being pumped at rates of 95 percent of safe yield: Buffalo Aquifer West Fargo Aquifer Moorhead Aquifer Kragnes Aquifer Remaining urban core demands are able to be made up by supplies from municipal treated water storage and flows in the Sheyenne and Red Rivers (less minimum in-stream flows of 7 and 3 cfs, respectively).	Information/Education 1. Drought Action Team activates the chain of contacts outlined in Drought Action Organization Chart (Figure 18) informing them of changing supply conditions. Streamflow forecast information is then compiled from data furnished by contacts in the Army Corps of Engineers. 2. Cities and utilities publicize current status which could limit system capabilities, as well as costs of supply augmentation for the utility and consumers. Implement Conservation Programs 1. Utilities increase monitoring and maintenance of water meters. 2. Utilities step up leak detection and repair programs.
WITH SUPPLY ALTERNATIVE II (TENNANT)	
The same conditions apply, with the exception that minimum in-stream flows in the Red and Sheyenne Rivers are now 168 and 51 cfs, respectively.	

TABLE 61 (continued)

DROUGHT EMERGENCY PLAN - URBAN CORE COMMUNITIES

CURRENT CONDITIONS	PUBLIC SECTOR ACTIONS
STAGE B	
WITH SUPPLY ALTERNATIVE VI (SRR)	
Streamflows in the Red and Sheyenne Rivers approach minimum in-stream flows of 7 and 3 cfs after withdrawals for municipal use. The combined supply from sources outlined in Stage A is less than the demands of the urban core communities.	Continue education and programs implemented in Stage A with the following additions:
The storage behind the low-head dam in the Red River must now be utilized to cover deficits.	Information/Education 1. Drought Action Team notifies contacts as shown in the Drought Organization Chart about use of additional supply sources. 2. Drought Action Team and utilities intensify public education explaining new supply augmentation methods using utility billing inserts and local media ads. Costs associated with potential actions in succeeding stages of drought are expressed.
WITH SUPPLY ALTERNATIVE II (TENNANT)	
Streamflows in the Red and Sheyenne Rivers approach minimum in-stream flows of 168 and 51 cfs after withdrawals for municipal use. The combined supply from sources outlined in Stage A is less than the demands of the urban core communities.	3. Utilities and cities distribute conservation booklets explaining less wasteful practices of water use and describing potential public actions in following stages.
Aquifer storage reserved for drought now becomes the primary source utilized to cover supply deficits. This storage includes the aquifers listed in Stage A for Alternative VI (SRR), as well as the West Fargo South and the Sheyenne Delta Aquifer. The storage behind the low-head dam in the Red River is now utilized to augment these supplies during peak periods.	Implement Conservation Programs 1. Cities request voluntary reductions in outdoor water uses. Lawn sprinkling on alternate days and off-peak hours is suggested. 2. Drought Action Team requests ground-water permitting authorities (Minnesota Department of Natural Resources and North Dakota State Water Commission) to survey current users and frequently monitor all major users. 3. Cities advocate voluntary retrofit with water-saving devices in free retrofit kits (toilet dams, low-flow buttons, and faucet aerator inserts).

TABLE 61 (continued)

DROUGHT EMERGENCY PLAN - URBAN CORE COMMUNITIES

CURRENT CONDITIONS	PUBLIC SECTOR ACTIONS
STAGE C	
WITH SUPPLY ALTERNATIVE VI (SRR) Storage behind the low-head dam is 60 percent depleted and the combined supply from sources outlined in Stages A and B is less than the demands of the urban core communities. The aquifer storage reserved for drought contingencies must now be utilized to cover supply deficits. This now includes the use of the West Fargo South Aquifer. WITH SUPPLY ALTERNATIVE II (TENNANT) The aquifer storage identified in Stage B is now depleted by approximately 30 percent.	Continue education and programs implemented in Stages A and B with the following additions: Information/Education 1. Mayors declare a drought emergency. 2. Drought action team notifies contacts as shown in the Drought Organization Chart about use of additional supply sources and emergency conditions. 3. Public education is expanded to include the explanation of general conservation techniques and enforcement policies for restrictions. Implement Conservation Programs 1. Cities advocate voluntary rationing to produce reductions of up to 10 percent. 2. Cities discontinue use of fire hydrants other than for extinguishing fires. 3. Cities survey large commercial and industrial users and request reduction in non-essential water uses.

TABLE 61 (continued)

DROUGHT EMERGENCY PLAN - URBAN CORE COMMUNITIES

CURRENT CONDITIONS	PUBLIC SECTOR ACTIONS
STAGE D	
WITH SUPPLY ALTERNATIVE VI (SRR)	
The programs implemented in previous stages have produced a reduction in average municipal use of approximately 15 percent. Low-head storage is completely deleted. Aquifer storage supplies developed in prior stages are reduced to 70 percent of original capacity.	Continue education and programs implemented in previous stages with the following additions. Information/Education 1. Drought Action Team notifies established contacts on the status of remaining supplies. 2. Cities and utilities establish "high profile" education campaign including contests, billboards, speakers, and school programs. 3. Cities post water conserving signs in public places.
WITH SUPPLY ALTERNATIVE II (TENNANT) The programs implemented in previous stages have produced a reduction in average municipal use of approximtately 15 percent. Aquifer storage supplies developed in prior stages are reduced to 70 percent of their original capacity.	Implement Conservation Programs 1. Drought Action Team requests frequent reports on withdrawals by all Ground-water users and carefully monitors the depletion of remaining supplies via ground-water permitting authorities. 2. Cities advocate voluntary rationing to produce reductions of up to 15 percent of average annual use. 3. Cities invoke ordinances calling for a mandatory sprinkling restriction on alternate days and off-peak hours (usually between 8 p.m. and 10 a.m.), with penalties (see Table 62). Similar reductions apply to all irrigators using municipal water for non-essential uses.

Public sector actions in Stage B include continuation of those activities begun in Stage A. New education and conservation programs focus on informing the public about the status of water facilities and request voluntary conservation. Data required to monitor ground-water withdrawals are requested from State agencies. Utility billing inserts, conservation booklets, and local media ads are now used to explain potential actions in succeeding stages, drought-related costs, and how to conserve water outdoors. A voluntary campaign to retrofit homes with water-saving devices is also begun. These devices include toilet dams, low-flow aerators, and flow-reducing inserts and would be available free at a central depot.

Stage C is implemented when the storage behind the low-head dam is 60 percent depleted and the combined supply from all sources outlined in Stages A and B is less than the demands of the urban core communities. The aquifer storage reserved for drought contingencies must now be utilized to cover deficits.

In Stage C, public sector actions include continuations of those activities begun in previous stages. The mayors now declare a drought emergency. The public information campaign is expanded to include explanations of conservation techniques. A voluntary water rationing program advocating a 10 percent reduction in residential, commercial, and industrial use is called for. Rationing programs may be based on average annual or winter water use, a per capita use value, or a fixed or variable percentage reduction across all user sectors. Reductions in other non-essential uses by residential, commercial, and industrial consumers are also requested. Accordingly, the city discontinues its non-essential uses such as fire hydrant flushing.

Stage D is the final stage in the Drought Emergency Plan. The low-head storage reservoir is completely depleted and 70 percent of the original aquifer storage remains. This value is based on safe yield data and reported pumping records. Prior conservation efforts have reduced demand by approximately 15 percent of average annual use.

A "high profile" public education program (including contests, billboards, speakers, and "water shortage -- please conserve" signs) is begun in addition to previous actions. Enforcement policies for mandatory conservation measures are also explained (Table 62). Frequent monitoring of ground-water pumping records and weather/streamflow forecasts is conducted to determine remaining aquifer storage and surface water supplies. Information may indicate a drought with a recurrence interval of 100 years or more is in progress. At this point, the Drought Action Team and the utility must evaluate the available water supply and forecast data to determine the amount of any further reductions. These reductions may be achieved through an intensified voluntary rationing program and mandatory sprinkling restrictions. Sprinkling restrictions limit lawn watering to alternate days and off-peak hours, usually between 8 p.m. and 10 a.m. Penalties for violations can involve a series of warnings as outlined in Table 62.

Data developed for year 2030 indicate that a 10-percent reduction in annual average municipal use would make this Drought Emergency Plan capable of providing water supplies to the urban communities in events beyond a 100-year recurrence interval drought. Additional reductions may be necessary under certain site-specific conditions including contamination of a source of supply.

TABLE 62

DROUGHT/EMERGENCY CONSERVATION PLAN PENALTIES

Violation Occurrences	Prohibited Uses	Excess Uses
First	Written warning via regular mail.	Written warning via regular mail
Second[a]	Written warning delivered by utility representative who will offer conservation tips and approved retrofit devices.	Surcharge Written warning delivered by utility representative who will offer conservation tips and approved retrofit devices.
Third[a]	Flow restrictor (1 gpm) installed for 48 hours. Installation and removal charges assessed.	Surcharge Flow restrictor (1 gpm) installed for 48 hours. Installation and removal charges assessed.
Additional[a]	Shutoff, plus reconnection charge of $25.	Surcharge Shutoff, plus reconnection charge of $25.

[a]Within one year of first occurrence.

3. Drought Emergency Plan - Water Supply Alternative II (Tennant)

The drought emergency plan for urban core communities utilizing water supply Alternative II (Tennant) is quite similar in form to the previously described drought emergency plan with water supply Alternative VI (SRR).

Alternative II (Tennant) and Alternative VI (SRR) are equally capable of providing all projected water needs of the urban core communities during a 50-year drought through the year 2030. So again, any reductions provided by water conservation measures become a margin of safety toward greater recurrence interval events. In addition, Alternative VI (Tennant) uses the same type of water supply facilities as Alternative IV (SRR). Therefore, a comparable operation plan is suitable for both alternatives. Due to these similarities, identical public actions are also appropriate.

The primary difference between the two alternatives is that a larger portion of the Red and Sheyenne River flows are commited to minimum in-stream flows. The additional volume of water to allow for these flows is large enough that the available low-head storage becomes relatively insignificant and the ground-water supply network must be extended to the Sheyenne Delta Aquifer. Specific adjustments which must be made in the drought emergency plan associated with Alternative VI (SRR) in order to address the special characteristics of Alternative II (Tennant) are shown in Table 61.

C. EMERGENCY WATER SUPPLY PLAN FOR RURAL COMMUNITIES

All rural communities obtain their water supplies from ground water. If they establish the facilities outlined in Tables 49 and 50 of Chapter VII, they will be able to provide water to their residents through the year 2030. This assumes that there is no facility failure, aquifer contamination, or shortage related to heavy ground-water use by others. Water supply emergencies would involve reductions in water demand which can be achieved through public

actions like those described in the drought emergency plans for the urban core communities and would provide a margin of safety in these emergencies. Sources of emergency augmentation include trucked-in water and supplies available from the reactivation of older municipal or individual systems. The emergency plan presented here is a general plan for rural communities which can be adapted by local officials according to their special circumstances.

The Emergency Water Supply Plan for Rural Communities (Table 63) includes three stages. Each stage represents a means of compensating for the loss of a certain percentage of municipal water supply capability. Such losses may possibly occur through facility failure or damage to the resources, such as well field contamination. In actual application, a community could enter the plan at any stage and, by taking the outlined Public Sector Actions in previous stages, achieve the desired reduction in demand.

The Emergency Action Team is composed of local government officials including the mayor, city council, utility management, city engineer, and county commissioners. The members of the team would be responsible for assessing the percentage loss in supply capability and then relaying this information to the appropriate County Emergency Services Office. This will activate the emergency network as previously described for the urban communities. In the event of contamination, the North Dakota State Department of Health or the Minnesota Department of Health - Division of Water Supply should also be contacted directly. Since the team also contains the major local officials, it would be appropriate for them to also take charge of initiating the other designated Public Sector Actions.

TABLE 63

EMERGENCY WATER SUPPLY PLAN - RURAL COMMUNITIES

CURRENT CONDITIONS	PUBLIC SECTOR ACTIONS
STAGE A	
System facility/resource loss is equivalent to 10 to 15 percent of average annual demand.	Information/Education 1. Emergency Action Team reviews the situation and contacts the appropriate State Department of Health and County Emergency Services Office. 2. Emergency Action Team initiates public education, explaining current conditions and associated costs. The team distributes conservation booklets describing less wasteful practices of water use and use restrictions. Implement Conservation Programs 1. Community invokes ordinance restricting lawn sprinkling and all outdoor water uses to alternate days and off-peak hours. 2. Community distributes free retrofit kits of water-saving devices. 3. Community increases system management activities involving meter monitoring, leak detection, and repair.

TABLE 63 (continued)

EMERGENCY WATER SUPPLY PLAN - RURAL COMMUNITIES

CURRENT CONDITIONS	PUBLIC SECTOR ACTIONS
STAGE B	
System facility/resource loss is equivalent to 20 to 30 percent of average annual demand. Rural communities presently served by CRWUA reactivate older supply systems, if operational. Other communities encourage the use of existing individually-owned wells.	Implement Public Sector Actions of Stage A with the following additions: 1. Mayor declares emergency situation. 2. Emergency Action Team notifies contacts of current situation. 3. Community officials speak at public meetings to explain reduction actions, rationing program, and potential actions if situation should worsen. Implement Conservation Programs 1. Community requests voluntary rationing to achieve additional reductions resulting in a savings of 30 percent of average annual use.

TABLE 63 (continued)

EMERGENCY WATER SUPPLY PLAN - RURAL COMMUNITIES

CURRENT CONDITIONS	PUBLIC SECTOR ACTIONS
STAGE C	
System facility/resource loss is equivalent to approximately 50 percent of average annual demand. Rural communities arrange for trucked-in water from other sources.	Implement the Public Sector Actions of Stages A and B with the following additions: Information/Education 1. Emergency Action Team notifies contacts of current situation. 2. Community officials go door-to-door to explain rationing guidelines and to point out appropriate reduction measures. Implement Conservation Programs 1. Community requests voluntary rationing to achieve additional reductions resulting in a savings of 50 percent of average annual use. 2. Communities ban outdoor water use.

Stage A is implemented when a loss of 10 to 15 percent of municipal water supply capability is anticipated. In the plan, this loss is mitigated with Public Sector Actions producing a comparable reduction in water demand. After making the appropriate contacts, the Emergency Action Team initiates a public education campaign to explain general water conservation practices and details of the restriction ordinance and retrofit distribution. The water facility maintenance program is also intensified. The water conservation practices, including restrictions and retrofit, are essentially the same as those previously described in the Drought Emergency Plan for the urban core communities. The same methods of enforcement are also applicable, though strong voluntary commitment to conservation could be expected under these emergency circumstances. The facilities maintenance programs of the rural communities are simpler than those of the urban core communities. Increased system management activities would consist of additional labor devoted to monitoring meters and nightly sewer flows to detect leaks and then repair them.

Stage B is implemented if a loss of 20 to 30 percent of average annual demand is expected. Argusville and Mapleton can possibly reactivate their older municipal supply systems. Other communities should encourage the use of existing individually owned wells. The emergency status is announced to the public through town meetings. Topics of discussion include details of a rationing program and potential actions if the situation should worsen. Possible rationing programs are mentioned in the discussion of the Drought Emergency Plan for urban core communities.

Stage C is implemented if losses in supply capability are approximately 50 percent or more. The rural communities must now arrange for trucked-in water from other sources. A door-to-door public education campaign could be used to

inform all residents of the necessary conservation measures involved in the rationing program. All non-essential outdoor use is banned, including lawn sprinkling and bulk water sales.

XII. CONCLUSIONS AND RECOMMENDATIONS

In this study, a fundamental distinction has been made between the urban core communities of Fargo, Moorhead, West Fargo, and Dilworth, and the remaining study area communities. The smaller communities comprising the latter group all rely on ground water and can meet projected future water needs with localized expansions of their water supply facilities. The specific expansions outlined in Tables 49 and 50 at the end of Chapter VII are recommended. The water resources required for the smaller communities were allowed for in the analysis of water supply alternatives for the urban core.

Using existing facilities and resources as a basis, the urban core communities are projected to require an additional 30.24 million gallons of water per day under extreme conditons in the year 2030. These conditions include 7-day, 50-year drought flows in both the Red and Sheyenne Rivers, coincident with projected maximum day water demands plus fire-flow requirements. The existing facilities' firm yields (i.e., water production with the largest pump out of service) along with treated water storage volumes are assumed in the above.

Of the five study area rivers investigated, the Red and Sheyenne Rivers are identified as logical future sources of part of the water supply for the urban core communities. These two rivers are currently used, while the other rivers experience substantial periods of zero flow under a 50-year drought.

Ground-water aquifers in the study area are also available for further development. The Buffalo, Moorhead, Kragnes, and West Fargo South Aquifers together can safely supply an estimated 1.68 billion gallons yearly in addition to current withdrawals.

However, one study area aquifer, the West Fargo Aquifer, is currently over-utilized. It is recommended that withdrawals from this aquifer be curtailed below the safe yield and that other sources be tapped to meet the excess demands.

The Sheyenne Delta Aquifer represents a very large potential water supply source outside the study area. The safe yield of this aquifer is much greater than the projected needs of the Fargo-Moorhead urban core. However, transmission distances would also be large -- on the order of 25 miles or more. In addition, large-scale development of the Sheyenne Delta Aquifer would require careful study of the effects on Sheyenne River flows and on the unique ecology of the Sheyenne Delta area.

The proposed Garrison Diversion would significantly increase streamflows in the Red and Sheyenne Rivers. If fully implemented, the diversion would slightly decrease the cost of future water supply facilities required for the urban core communities. However, the cost-ranking of alternative water supply schemes would not be affected.

Water supply alternatives in this study were based on two methods for determining in-stream flow requirements. The Tennant criteria call for municipal withdrawals from the rivers to be curtailed or cease when streamflows would fall below 30 percent of the annual mean. The Souris-Red-Rainy River Basins Comprehensive Study (SRR) criteria allow withdrawals until flow would fall below 7 and 3 cfs in the Red and Sheyenne Rivers, respectively. Flows below 30 percent of the annual mean would be divided equally between the two rivers so that each would be reduced to the same percent of mean annual flow. With the SRR criteria, flows would be augmented if necessary to maintain those minimum flows. Under normal flows, the two methods are equivalent. During any

but the most severe droughts, Tennant-based alternatives would result in more streamflow than SRR-based alternatives. However, Tennant-based alternatives cost considerably more than SRR-based alternatives.

Interconnections of Fargo with West Fargo and Moorhead with Dilworth appear to be necessary for supplying water to the urban core communities in the most cost-effective manner. The same sources would have to be tapped without the interconnections, but since parallel systems would be required, this would be at a higher total cost (e.g., Dilworth would need Buffalo Aquifer supplies whether acquired directly or through an interconnection with Moorhead). In addition, an interconnection from Fargo to West Fargo could have legal bearing on the retention of West Fargo's water rights to the Sheyenne River and Lake Ashtabula.

An interconnection between the two largest communities, Fargo and Moorhead, also appears to be desirable for several reasons:

- Moorhead-Dilworth cannot meet year 2000 demands under drought conditions without additional storage. The interconnection would delay the need for reservoir construction.

- The interconnection would allow new ground-water treatment process expansion to take place primarily at the Moorhead plant and new surface-water treatment expansion to take place at the Fargo plant. This would provide economies of scale and continuity at the treatment plants. It would also simplify raw water piping schemes. The Moorhead plant is located at the east edge of the service area close to the main ground-water sources. This minimizes the piping and in-town trenching required for raw water lines from the aquifers. However, it would increase the piping and in-town trenching required if a new river intake pipe were required in Moorhead. The Fargo treatment plant is optimal for new surface water treatment. The plant is close to the Red River, minimizing expansion costs for a new intake pipe. It is also already

connected to the Sheyenne River. If expansion to aquifers south of Fargo is required, the transmission lines may be connected to the Fargo plant via the Sheyenne Diversion pipeline.

- The interconnection will benefit both parties. No cross-flow would occur under normal conditions. In times of drought, cross-flow could occur in either direction. The more frequent occurrence would be cross-flow from the Fargo side of the river to the Moorhead side, which would only occur in droughts when the Red River flows approach minimum in-stream requirements. In very severe droughts (greater than 50-year recurrence interval), however, ground-water sources carry a larger proportion of demand, and cross-flow from the Moorhead to the Fargo side may occur.

The least costly sources of supply vary somewhat based on the quantities required from the sources; however, general conclusions can be made subject to specific exceptions. A generalized rank order for water supplies is as follows:

1. Expand Kragnes Aquifer
2. Expand Moorhead Aquifer
3. Expand Buffalo Aquifer
4. Construct in-stream storage
5. Construct off-stream storage
6. Develop West Fargo South Aquifer
7. Develop Sheyenne Delta Aquifer

Other factors being equal (costs, environmental impacts, social impacts, etc.), ground-water sources are preferred over surface-water storage. Although both sources have been sized to satisfy 50-year drought demands, ground-water supplies continue to provide water under more extreme droughts. When the surface-water storage volume is consumed, no more is available.

This investigation evaluated alternative water supply schemes on the basis of costs; recreational potential; and impacts on environmental, social, and cultural resources. This screening eventually focused attention on two alternatives -- II (Tennant) and VI (SRR).

Alternative VI (SRR) uses the SRR operating plan, which allows municipal withdrawals from the Red River until flow would drop below 7 cfs. Alternative II (Tennant) uses the Tennant-based operating plan, which restricts withdrawals when flows would fall below 30 percent of the annual mean. During moderate droughts, Red River streamflows with the Tennant operating plan would be up to 31 cfs greater than with the SRR plan; this would maintain flows preferable from a fishery standpoint for longer periods of time. But neither plan would prevent flows during severe droughts from dropping below thresholds considered desirable for preservation of healthy aquatic resources.

In more detailed stages of planning, studies should be conducted to determine more accurately the streamflow needs of the biota in the study area. These needs should receive full consideration in future water supply planning. Alternative methods of establishing streamflow needs consider seasonal variations in streamflow and recognize the specific needs of fish species in the particular stream. Methodologies for the Determination of Stream Resource Flow Requirements by Stalnaker and Arnette is a recent review of these methods.

As presently formulated, Alternative II (Tennant) requires massive aquifer development in lieu of river withdrawals and its costs (nearly $32 million for water supply exclusive of treatment) are several times higher than those for Alternative VI (SRR). Should further study show the streamflow needs to be less than the Tennant-based criteria used in this investigation, these costs might be reduced considerably.

Alternative VI (SRR) includes expanded development of the Moorhead, Kragnes, and Buffalo Aquifers to their safe yields and construction of a larger Red River low-head dam with approximately 1,250 acre-feet of usable storage (an estimated 1,900 acre-feet total storage). This alternative would interconnect the four urban core communities of Fargo, Moorhead, West Fargo, and Dilworth into a subregional water supply system. Total present worth for capital costs and operation, maintenance, and repair costs are $5,891,000 and $6,157,000, respectively. These are equivalent to approximately $1,150,000 per year for the 46 years remaining in the planning period (1984 to 2030).

Local implementation of Alternative VI (SRR) could be done in phases. The first phase would include constructing interconnections between Fargo and West Fargo and between Moorhead and Dilworth. It would also include laying the legal, fiscal, and administrative groundwork for a subregional water supply facility eventually to jointly serve Fargo, Moorhead, West Fargo, and Dilworth. Examples of this groundwork include: 1) making the decision to create an interconnected system, 2) deciding upon the means of regulating and administering the system (e.g., create an Urban Water Supply Commission), 3) determining the conditions and limitations, if any, under which cross-flow would be allowed, and 4) making decisions on financing and operating the new regional facilities.

It is recommended that several studies be conducted in connection with in-stream reservoir storage on the Red River. One study should more accurately determine the existing usable storage behind the low-head dam in Fargo-Moorhead. The results will help establish the timing for expanded aquifer development. Other studies would assess the relationship between increases in dam height and increases in usable storage, maximum usable storage within the primary banks, Red River sedimentation volumes and rates, and the effects of increased dam height on flood levels. These studies are prerequisites to enlarging the reservoir on the Red River for the benefit of all the urban core communities.

Local, State, and Federal interests must cooperate in developing and implementing an equitable and mutually acceptable water supply plan for the Fargo-Moorhead urban study area.

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